The 3rd International Conference on Conservation Agriculture in Southeast Asia

Hanoi · 10th > 15th December 2012

Conservation Agriculture and Sustainable Upland Livelihoods

Innovations for, with and by Farmers to Adapt to Local and Global Changes
The 3rd International Conference on Conservation Agriculture in Southeast Asia

Conservation Agriculture and Sustainable Upland Livelihoods
Innovations for, with and by Farmers to Adapt to Local and Global Changes
- Proceedings

Hanoi, Vietnam
December 10-15, 2012
www.conservation-agriculture2012.org
The 3rd International Conference on Conservation Agriculture in Southeast Asia

Conservation Agriculture and Sustainable Upland Livelihoods: Innovations for, with and by Farmers to Adapt to Local and Global Changes

Proceedings of the Conference held in Ha Noi, Vietnam
December 10-15, 2012

Editors

Mr. Damien Hauswirth (CIRAD - UPR SIA)
Dr. Pham Thi Sen (NOMAFSI)
Mr. Oleg Nicetic (University of Queensland)
Dr. Florent Tivet (CIRAD - UPR SIA)
Pr. Le Quoc Doanh (MARD)
Pr. Elske Van de Fliert (University of Queensland)
Dr. Gunnar Kirchhof (University of Queensland)
Mr. Stéphane Boulakia (CIRAD - UPR SIA)
Mr. Stéphane Chabierski (CIRAD - UPR SIA)
Dr. Olivier Husson (CIRAD - UPR SIA)
Mr. André Chabanne (CIRAD - UPR SIA)
Dr. Johnny Boyer (CIRAD - UPR SIA)
Dr. Patrice Auffray (CIRAD - UPR SIA)
Mr. Pascal Lienhard (CIRAD - UPR SIA)
Mr. Jean-Claude Legoupil (CIRAD - UPR SIA)
Mr. Matthew L. Stevens (ScienceScape Editing)

Co-published by

Organized with the financial support of
With the kind assistance of

Special thanks to
Matthew Stevens, ScienceScape Editing, Sydney, Australia
Peter Biggins, CIRAD, Nogent sur Marne, France
Christine Casino, CIRAD UPR SIA, Montpellier, France
Patricia Doucet, CIRAD, Montpellier, France
Martine Duportal, CIRAD, Montpellier, France
Cécile Fovet-Rabot, CIRAD, Montpellier, France
Philippe Radigon, CIRAD, Montpellier, France
Tran Thi Chau, CIRAD Regional Direction, Vietnam
Ronald Jeff Esdaile, Agricultural Consultant, Sidney, Australia
Samran Sombatpanit, WASWAC, Thailande
Li Hongwen, China Agricultural University, Conservation tillage research Center, China
Gunnar Kirchhof, University of Queensland, Brisbane, Australia
Nguyen Thi Thanh Thuy, NOMAFSI
Minh Thi Le Do, NOMAFSI
Dieu Huong Le, NOMAFSI

Citation
Foreword

Agriculture in whatever age, under whatever natural, economic and social conditions, has to feed the human being. To fulfil this mission, the sector has to overcome continuous and changing challenges to achieve notable developments. The Green Revolution, through developing and introducing high-yielding crop varieties and advanced crop management techniques, saved billions people from starvation. The advent of Biotechnology, in its turn, has speed up the agricultural growth to meet food demands of the world’s booming population.

Continuous demographic pressure and rapid market integration have created necessity to further agricultural developments to meet not only food security, but also the increased demands for nutrition security, food safety, energy, etc., while the global climate change has created needs for capturing synergies between agricultural production and environmental protection. New breakthroughs to trigger the second Green Revolution have therefore become necessary. Thus, it is now the right time for us to consider the means to make “the Double-Green Revolution” to become a reality.

Conservation Agriculture (CA) has demonstrated potential to meet this goal through designing and promoting the adoption of environment-sound and climate-resilient agricultural production systems. Increasing interests and efforts have been given to CA research for development in the Southeast Asia during the last 15 years. As a result, a new stage has been reached with the formation of the Conservation Agriculture Network for Southeast Asia (CANSEA) in 2009, in which efforts have been maintained to adapt concepts of CA to small scale farmers dealing with a great diversity of climate, land, topography and economy conditions. Enormous inputs are needed for the Southeast Asia to design specific and diverse CA innovations appropriate for local farmers and to promote their large scale adoption. This requires involvement of a wide range of stakeholders from both private and public sectors.

This is the reason for us to gather together at the 3rd International Conference on Conservation Agriculture in Southeast Asia entitled “Conservation Agriculture and Sustainable Upland Livelihood: Innovations for, with and by Farmers to Adapt to Local and Global Changes”. At this conference, the results of a tremendous amount of creative work dedicated to CA development worldwide will be presented. The methods and tools for designing relevant CA innovations and the experience and proposals for their adoption will be shared.

This volume compiles a picture portfolio of abstracts selected through a peer-review process for oral and poster presentations at the conference.
Main topics addressed in this volume include (1) Agrarian transitions in the Southeast Asian uplands and highlands; (2) Impacts of agricultural systems on agricultural ecosystem sustainability; (3) Farming and cropping system design to sustainably intensify production; (4) Synergizing concepts of CA and Agroforestry; (5) Potentials and constraints of CA for rural development, and (6) Conditions, strategies, barriers and opportunities for scaling-up CA.

This compilation represents a state and the art of CA research for development worldwide and the possible applications for the Southeast Asia. We wish it to serve as a basis to feed debates on conditions and strategies towards large adoption of CA by uplands farmers in the region.

Credit for the quality of this volume goes first and foremost to the authors. All of those who submitted abstracts have part in the conference success. Credit also goes to the Scientific Committee members for their invaluable time and efforts to carefully read and evaluate 250 submissions in total, and to the Organization Committee members for their hard work to coordinate the job.

Credit must also go to the French Development Agency (AFD), the French Ministry for Foreign and European Affairs (MAEE), the French Global Environment Facility (FFEM), the Australian Centre for International Agriculture Research (ACIAR), the Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM), the World Association for Soil and Water Conservation (WASWAC) the Vietnam Academy for Agricultural Sciences (VAAS) and Northern Mountainous Agricultural and Forestry Science Institute (NOMAFSI) for their valuable supports to the Conference and publication of this volume.

With donation and supports of all the above mentioned, this volume is more than the conference proceedings. It will serve as both motives and guidance for growing number of actors from all sectors, academic, industrial and policy, public and private, involving in CA research and development in the Southeast Asia and the world as a whole.

Hanoi, 26 November 2012

Dr. Bui Ba Bong
Vice-Minister of Agriculture and Rural Development of Vietnam
Farmers’ perception of soil erosion as a risk to their livelihood – scenario analysis with farmers in the northern mountainous region of Vietnam
Oleg Nicetic, Amanda Lugg, Pham Thi Sen, Le Thi Hang Nga, Le Huu Huan, Elske van de Fliert

CHAPTER 2. DESIGN OF AGRICULTURAL SYSTEMS

Subtopic 1. Overall approaches and transdisciplinary design

Keynote 2: Understanding and using socioeconomic data on ethnic farmers to prepare for implementation and scaling up of CA projects
Christian Culas

Framework, dynamics and challenges of transdisciplinary research-for-development on sustainable land management in the north-western highlands of Vietnam
Elske van de Fliert, Pham Thi Sen, Oleg Nicetic, and Le Quoc Doanh

Assessing the contribution of participatory approaches to sustainable impacts of agricultural research-for-development in the northwest highlands of Vietnam
Nguyen Huu Nhuan, Oleg Nicetic, Lauren Hinthorne and Elske van de Fliert

Subtopic 2. Adaptive research for development: methods, tools, indicators

Keynote 3: Adaptation of direct-seeding mulch-based cropping systems for annual cash crop production in Cambodian rainfed uplands
Stéphane Boulakia, Stéphane Chabierski, Phâlly Kou, Sona San, Rada Kong, Vira Leng, Veng Sar, Kimchhorn Chhit, Lucien Séguy

Adaptive participatory research to develop innovations for sustainable intensification of maize-based farming systems in the northern uplands of Vietnam
Pham Thi Sen, Le Huu Huan, Do Sy An, Dang Van Cong, Trinh Van Nam, Oleg Nicetic, Elske van de Fliert, Le Quoc Doanh

Complementing traditional crop cultivation with agro-ecological interventions: supporting farmer innovations in eastern India
Vidhya Das and Achyut Das

‘Oasis sofa’: application of conservation agriculture in urban vegetable production
Manuel Reyes, Don Immanuel Edralin, Lyda Hok and Kieu Ngoc Le

Crop associations and successions in conservation agriculture: implications for system design, training and extension
Olivier Husson, André Chabanne

Save and grow: minimum-tillage IPM in rice-based potato cropping in Vietnam
Ngo Tien Dung, Johannes W.H. Ketelaar, Alma Linda M. Abubakar

Community seed system as a mechanism for delivery of conservation agriculture in the marginal uplands of the Arakan Valley, Cotabato, the Philippines

Community-based resource assessment and management planning for the rice terraces of Hungduan, Ifugao, Philippines
Margaret M. Calderon, Nathaniel C. Bantayan, Josefina T. Dizon, Asa Jose U. Sajise, Analyn L. Codilan and Myranel G. Salvador
Evaluation of a plant-fibre-based stormwater filter for improving groundwater recharge quality
Manoj P. Samuel, S. Senthilvel and D. Tamilmani 128

Institutional and policy options for improving the economic value of grassland in the mountainous regions of Vietnam: a case study in Son La Province
G. Duteurtre, Pham Thi Hanh Tho, Trinh Van Tuan, Stephen Ives 130

Assessing agricultural sustainability of current farming systems to guide alternative management strategies: a case study in the highlands of Vietnam

Redox potential (Eh) and pH as indicators of soil conditions: possible application in design and management of conservation agriculture cropping systems
Olivier Husson 138

Subtopic 3. Use of models

Keynote 4: Reconciling experimentation and modelling in the design of alternative agricultural systems
Pablo Tittonell, Felix J.J.A. Bianchi, Jeroen C.J. Groot, Egbert A. Lantinga, Johannes M.S. Scholberg and Walter A.H. Rossing 142

Agro-climatic modelling to assess the feasibility of introducing a supplementary crop during spring in the high valleys of mountainous northern Vietnam
Luu Ngoc Quyen 156

Can more irrigation help in restoring environmental services provided by upper catchments? A case study in the northern mountains of Vietnam
Damien Jourdain, Esther Boere, Marrit van den Berg, Dang Dinh Quang, Cu Phuc Thanh, François Affholder 161

Models for assessing farm-level constraints and opportunities for conservation agriculture: relevance and limits of the method, identified from two case studies
François Affholder, Damien Jourdain, Veronique Alary, Dang Dinh Quang, Marc Corbeels 164

CHAPTER 3. SYNERGIZING CONSERVATION AGRICULTURE AND AGROFORESTRY

Buffering soil water supply to crops by hydraulic equilibration in conservation agriculture with deep-rooted trees: application of a process-based tree–soil–crop simulation model to parkland agroforestry in Burkina Faso
Meine van Noordwijk, Rachmat Mulia, Jules Bayala 176

Conservation agriculture with trees in sub-Saharan Africa: case studies from four countries
Jeremias G. Mowo, Jonathan Muriuki and Saidi Mkomwa 180

Potential tree-crop combinations for conservation agriculture with trees in Vietnam
Hoang Thi Lua, Tran Nam Thang, Nguyen Quoc Binh, Tran Van Hung, Giang Thi Thanh and Delia C. Catacutan 183

Improving productivity and services of trees in slash-and-burn systems. What lessons from assisted natural regeneration in DR Congo can be applied to other humid tropical regions?
Participation of farmers in temperate fruit development in the north-western highlands of Vietnam
Pham Thi Vuong, Nguyen Van Chi, Tran Van Dat, Pham Van Ben 188

Cultural methods for improving production of Tam Hoa plums in Son La, Vietnam
Nguyen Thi Thuy, Pham Thi Vuong, Le Duc Khanh, Nguyen Nam Hai, Do Xuan Dat, Nguyen Van Chi, Nguyen Thi Thanh Hien 190

Chapter 4. Conservation Agriculture and Ecosystem Services

Keynote 5: Can conservation farming practices ensure agricultural ecosystem stability?
Neal Menzies, Andrew Verrell, Gunnar Kirchhof 202

When, how and why does no-till farming work?
J.C.M Sá, F. Tivet, R. Lal and L. Séguy 221

From land conversion to diverse biomass-C inputs under NT: Changes on SOC stocks and humification degree

Enhancing soil fertility and quality through conservation agriculture in the acid savannah grasslands of northern Laos
Pascal Lienhard, Moundavi Manivong, Bounma Leudphanane, Somchay Chantavong, Phakhphoom Tantachasatid and Johnny Boyer 227

Differential effects of biochar on soil organic carbon dynamics in two agricultural soils
Sudip Mitra, Pooja, S. Manzoor, T. Bera and A.K. Patra 229

Soil management systems and how winter crops affect soil organic phosphorus cycle
Ademir Calegari, Tales Tiecher, Danilo Rheinheimer dos Santos, Marcos Antônio Bender, Rogério Piccin, Elci Gubiani, Roque Junior Sartori Bellinaso, Carlos Alberto Casali 232

Diversity and structure of soil macrofauna communities under plant cover in a no-till system in Cambodia
Stéphane Boulakia, Lucien Seguy, Phakhphoom Tantachasatid, Somprach Thanisawanyankura, Vira Leng, Johnny Boyer 234

Recovery of soil macrofauna diversity through organic fertility patches: consequences for soil erosion in the uplands of northern Vietnam
P. Jouquet, T. Doan Thu, T. Henry-Des-Tureaux, D. Orange, J.L. Janeau, T. Tran Duc 236

Connectivity between natural habitats of Agusan Marsh floodplain and rice fields for rice pest management
Rowena P. Varela 238

Farmer-friendly erosion control measures in maize-based systems of the northern mountainous region of Vietnam
Gunnar Kirchhof, Nguyen Hoang Phuong, Trinh Duy Nam, Oleg Nicetic 240

Erosion on steep and fragmented lands: mitigation potential of soil conservation for maize cropping in north-western Vietnam
Tuan Vu Dinh, Thomas Hilger, Erisa Shiraishi, Gerhard Clemens, Lee MacDonald, Georg Cadisch 243

No-till mulch-based maize cropping on sloping lands in northern Vietnam reduces soil loss and surface runoff
Tran Sy Hai, Didier Orange, Tran Duc Toan, Pham Dinh Rinh, Dorian Decraene, Delphine Zemp, Nguyen Duy Phuong, Jean-Louis Janeau, Pascal Jouquet, Christian Valentin 246
Bed planting improves productivity of winter wheat in irrigated areas of Azerbaijan
I. Jumshudov, A. Nurbekov, H. Muminjanov, A. Musaev and S. Safarli 250

Conservation agriculture including cover crops and crop rotation can improve maize yield
Ademir Calegari, Antonio Costa, Danilo Rheinheimer dos Santos, Tales Tiecher, Carlos Alberto Casali 253

Yield, biomass and soil quality of conservation agriculture systems in the Philippines
Agustin R. Mercado Jr, Vic Ella and Manuel Reyes 256

Technical efficiency of wheat production under different cropping systems in Nineveh province, Iraq: a stochastic frontier production function analysis
Mohammed Jabar Abdulradh, Malcolm K. Wegener, and Kamel Shideed 259

Vermi-compost to improve tomato production in Bangladesh
S. T. Hossain, M. J. Uddin and H. Sugimoto 262

Potential of minimum-tilled maize + legumes for double cropping on high-elevation Acrisols in north-western Vietnam: a case study in Lai Chau province
Nguyen Phi Hung, S. L. Ranamukhaarachchi 264

Productivity of upland rice–bean intercropping under intensive tillage and no-tillage with organic and mineral fertiliser inputs on ferralitic soil of Malagasy highlands
Manitranirina Henintsoa, Andry Andriamananjara, Tantely Razafimbelo, Lilia Rabeherisoa, Thierry Becquer 267

Deep tillage and mulching increase soil moisture storage and thus productivity of maize–wheat in the outer Himalaya foothills
Sanjay Arora, Vikas Sharma and V.K. Jalali 269

Trials of tillage and fertiliser rate in winter wheat in the Aral Sea basin, Uzbekistan
A. Nurbekov, T. Friedrich, H. Mauminjanov, R. Ikramov, Z. Ziyadullaev 272

CHAPTER 5. SOCIAL AND ECONOMIC IMPLICATIONS OF CONSERVATION AGRICULTURE

Conservation agriculture as an alternative to plough-based cassava cropping in the upland borders of Kampong Cham, Cambodia: preliminary results of extension
S. Chabierski, K. Rada, S. Sona and S. Boulakia 282

Potential of conservation agriculture as an alternative to maize monocropping in mountainous areas of Vietnam
Damien Hauswirth, Hoang Xuan Thao, Nguyen Quang Tin, Dam Quang Minh, Nguyen Van Sinh, Le Viet Dung, Nguyen Phi Hung and Ha Dinh Tuan 285

On-farm performance evaluation of conservation agriculture production systems in the central middle hills of Nepal
Bikash Paudel, Theodore Radovich, Susan Crow, Jacqueline Halbrendt, Catherine han-Halbrendt, B. B. Tamang, Brinton Reed and Keshab Thapa 289

Conservation agriculture adoption in Lake Alaotra, Madagascar
Eric Penot, Raphael Domas, Andriatsitohaina Rakotoarimanana and Eric Scopel 292

Parametric versus nonparametric approaches to assessing the performance of zero-tillage wheat in rice–wheat culture on the Indo-Gangetic Plains
Shyam Kumar Basnet 295

Double planting maize plus ginger in Nepal
Shree Prasad Vista, Kabita Basnet 298
Maize expansion in Xieng Khouang province, Laos: what prospects for conservation agriculture?
Jean-Christophe Castella, Etienne Jobard, Guillaume Lestrelin, Khamla Nanthavong, Pascal Lienhard

CHAPTER 6. CONDITIONS, STRATEGIES, BARRIERS AND OPPORTUNITIES FOR SCALING-UP CONSERVATION AGRICULTURE

Keynote 6: Opportunities for scaling up conservation agriculture: barriers, conditions and strategies
Amir Kassam, Theodor Friedrich, Francis Shaxson, Jules Pretty

Adoption of conservation agriculture by small-scale farmers in southern Honduras
Allan J. Hruska and Luis Álvarez Wlechez

Policy for the adoption of conservation agriculture in Mexico
Matthew Fisher-Post

Conservation agriculture in DPR Korea: opportunities and challenges
Pralhad Shirsath, Antony Penney, Jon Dong Gon

Institutional framework to boost the adoption of conservation agriculture in small-scale farming - lessons from northern Cameroon
O. Balarabé, O. Husson, S. Boulakia, F. Tivet, A. Chabanne, L. Seguy

Conservation agriculture extension among smallholder farmers in Madagascar: strategies, lessons learned and constraints
Rakotondramanana, Tahina Raharison, Frank Enjalric

Public–private partnership to promote conservation agriculture: rice millers as an entry point to scale up innovation in rainfed lowland rice fields in Lao PDR
Patrice Autfray, Ranjan Shrestha, Jean-Claude Legoupil, Lanlang Phanthanivong, Khamkeo Panyasiri

CHAPTER 7. INSTITUTIONAL VIEWPOINTS

Conservation agriculture production systems to improve rural livelihoods: the Sustainable Agriculture and Natural Resources Management Collaborative Research Support Program
Adrian Ares, Keith M. Moore, and Michael J. Mulvaney

Official development assistance institutions and conservation agriculture promotion
Jean-Luc François, Olivier Gilard, François Jullien

Conservation Agriculture With Trees, a form of Agroforestry - an institutional perspective
Meine van Noordwijk, Denis Garrity, Delia C. Catacutan

GLOSSARY

POSTFACE
Background

In recent decades, demographic pressure, rapid market integration with the reinforcement of contract-farming relationships, and a cap on agronomic progress in lowland areas have been key drivers in Southeast Asia of agrarian system dynamics, which mainly involve small-scale family farmers who are subject to numerous constraints. These dynamics have been notably characterized by various forms of agricultural intensification in upland areas alongside the emergence of critical sustainability issues.

In the near future, agricultural production is expected to be further intensified to meet rising demand for agricultural products linked to demographic transitions and changes in consumption habits. This intensification will bring with it greater tension between the productive dimensions of agricultural ecosystems and long-term sustainability attributes (efficiency, self-reliance, resilience, stability, autonomy, equity, etc.).

Small-scale farmers will necessarily have to adapt to those local and global changes. However, the adaptation process has to deal with constraints that are mainly environmental (water, soil and food pollution, soil fertility, etc.) but also social (competition for land use, safety of agricultural products) and economic, while in some cases possibly being associated with opportunities for change (carbon market, added-value for organic products, orientation of development funds towards adaptation to climate change, etc.).

This also creates needs for innovations enabling stakeholders to better keep abreast with on-going dynamics, adapt to local and global changes and drive ecosystem sustainability. Methods and tools for designing relevant innovations, the kinds of innovations to be proposed, and the agricultural models to be promoted are concerns widely shared by diverse countries, irrespective of local conditions.

Conservation agriculture has proved to have potential for increasing production and reducing the environmental impacts of agriculture in several countries, including Argentina, Brazil, China, India, the USA, Australia, totaling more than 100 million hectares worldwide. However, most of this area remains farmed by large-scale farmers, while the dissemination of conservation agriculture within small-scale family farming systems remains a major development challenge, with a need to enlarge the scope of the technological, organizational, economic and social innovations to be designed to solve the adaptation issues faced by small-scale farmers.
This particularly calls for coordinated action involving public research, development organizations, the private sector and donors to remove structural constraints for up-scaling (training - farmers, extension workers, engineers - supply chains for specific inputs - seeds, equipment -, provision of services, recognition of a specific quality for agricultural products derived from conservation agriculture, etc.).

Within this context, this conference aimed to:
- characterize drivers of agrarian / farming system changes in Southeast Asia
- analyse the impact of those changes on the sustainability of agricultural ecosystems
- identify, assess and design innovations related to conservation agriculture that provide possibilities for small-scale family farmers to sustainably intensify agricultural production while improving their ability to adapt to local and global changes.
- discuss conditions and strategies to widely extend conservation agriculture with small-scale farmers

The Conference was supported by the PAMPA consortium -which involves the French Development Agency (AFD), the French Ministry for Foreign and European Affairs (MAEE), the French Global Environment Facility (FFEM)-, by the Australian Centre for International Agriculture Research (ACIAR), by the World Association of Soil and Water Conservation (WASWAC) and by the Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM).

It involved scientists from several Institutes working on Research for Development in Asia, including the North Carolina Agricultural and Technical State University (AT), the Virginia Polytechnic Institute and State University (Virginia Tech) IRD, CNRS, the Hanoi University of Agriculture and the Vietnamese Academy for Agricultural Sciences (VAAS).

The Conference was jointly organized by CIRAD, NOMAFSI and the University of Queensland as part of actions within the scope of international cooperation. It was part of several research for development projects targeting sustainable development of Uplands, including the ADAM Project “Support to Extension of Conservation Agriculture in Vietnam” and the project “Improved market engagement for sustainable upland production systems in the north-western highlands of Vietnam”.

The Conference sought to build interdisciplinary scientific knowledge through contributions from the agricultural, economic and social sciences, and placed non-exhaustive emphasis on upland livelihoods and conservation agriculture in Southeast Asia. Studies that analyses farming system changes and deals with innovations related to conservation agriculture likely to contribute to the sustainable intensification of uplands were more specifically presented.
Chapter 1

Agrarian transitions in uplands and highlands and its consequences on sustainability of agricultural ecosystems

Vietnam
Irrigated rice plain with slopes bared for maize cultivation in the background

D. Hauswirth, Moc Chau, 04/2010
Keynote 1: Agrarian transition and farming system dynamics in the uplands of South-East Asia

Jean-Christophe Castella*1

1Institut de Recherche pour le Développement, UMR 220 GRED – IRD UPV Montpellier 3, France

*Corresponding author: j.castella@ird.fr

Abstract

In recent decades, agrarian landscapes and livelihoods in the uplands of South-East Asia have undergone dramatic changes. Farming households have had to adapt to the mounting influence of global drivers of change in an increasingly connected world (e.g. market integration, economic policies, environmental regulations, climate change). As a result, agrarian societies -with agriculture as the main occupation, the most important economic activity and the dominant ideology for rural development- have shifted to societies increasingly based on industrial production and services. These rapid and profound societal and environmental transformations constitute the ‘agrarian transition’.

In South-East Asia, the agrarian transition has been influenced by megatrends such as the commoditisation of agriculture, the increasing divide between different forms of agriculture (e.g. agribusinesses versus smallholders) and the diversification and de-agrarianisation of livelihoods. These trends are driven by a combination of factors, such as demographic changes, market forces and government policies that differentially affect local land uses depending on the stage they have reached in the agrarian transition. From a bottom-up perspective, the agrarian transition can be described as the rapid accumulation and convergence of multiple local land use trajectories. From there, local trajectories of change can be classified into a limited number of evolutionary pathways.

Locations (villages, districts) that evolve along the same pathways but at a different pace or with a time-lag can learn from each other (e.g. avoid repeating the same mistakes). This can facilitate decision-making in times of uncertainty if institutional mechanisms are in place to support exchanges across scales and sectors. Furthermore, the identification of windows of opportunities for conservation agriculture will facilitate the design of appropriate technologies and spatially differentiated policies.

Key words

Land use transitions, commoditisation of agriculture, livelihood vulnerability, de-agrarianisation
I. Land use trajectories and the agrarian transition in South-East Asia

1) The origins of South-East Asian agriculture: rice civilisations and commercial plantations

Three main types of agriculture can be distinguished in South-East Asia: swidden agriculture, lowland paddies and commercial crops (De Koninck 2005).

Swidden agriculture has existed for thousands of years in all tropical forests. It covers a wide range of cultivation practices (van Vliet et al. 2012) and is still the dominant form of agriculture in many rural upland areas in South-East Asia (Mertz et al. 2009). It is given multiple designations according to authors: shifting cultivation (Watters 1960; Conklin 1961; Spencer 1966; Fox et al. 2000), swidden cultivation (Conklin 1954) and slash-and-burn agriculture (Kleinman et al. 1995; Brady 1996; Fujisaka et al. 1996). All these terms refer to the alternation of cropping and fallow phases. This form of agriculture does not generate large surpluses and is therefore associated with low population densities. Mazoyer and Roudart (1997) estimate that swidden agriculture makes it possible to feed a maximum of 10 to 35 inhabitants per square kilometre, depending on the duration of fallow and the annual basic needs per person. Indeed, with low population densities this practice does not cause deforestation, since the cropping phase is short (1–3 years) and the fallow duration is long (10–20 years). Return on labour is high, but return on land is low, because one must take into account the whole area (crop + fallow) that allows the swidden system to maintain itself. Swidden agriculture can maximise return on labour when land resources are relatively abundant: the forest landscape is converted temporarily and then left to regrow. Swidden systems usually require some mobility from the communities who practise them, although rotation or displacement of the fields does not always imply habitat displacement. Often associated with other forms of forest exploitation such as hunting-gathering, swidden agriculture has its main purpose in food production and self-subsistence. It used to be and is still practised today by ethnic minority groups in the mountains of mainland South-East Asia and by the Dayak of Borneo.

In South-East Asia, the historical process of agricultural colonisation of forest areas was also driven by a sociotechnical model of agricultural production characterised by rice intensification in terraced lowlands thanks to improved water control and management. Irrigated rice cultivation is based on a strongly hierarchical system of labour and land control, as opposed to the more individualistic management of forested land practised by swiddeners. Initially, the technical choices (i.e. paddies v. swiddens) probably lay at the origin of the differentiated social rules. But later, the societal achievements appear decisive in the permanence of the lowland model of agriculture. Irrigated lowland agriculture is inseparable from the feudal societies such as Javanese and Balinese Indonesia, the Kinh in the deltas of Vietnam or the Tay/Thai in the mountains of mainland South-East Asia.
Long before the colonial era this form of rice cultivation was linked to dominant civilisations, such as those that emerged on the alluvial plains and deltas of the Irrawaddy, Chao Phraya, Red and Mekong rivers. Originally, rice surpluses allowed societies to maintain castes of artisans, nobles and clergy that have gradually structured rice civilisations (Geertz 1954; Hanks 1972; Conklin 1980; Gourou 1984; Diamond 1997). With the development of trade these surpluses could be redistributed or exchanged within the region or exported outside South-East Asia.

Since the colonial period, other areas were cleared for the development of commercial crops such as coffee, rubber and oil palm. The development of cash crops followed the takeover by the colonial powers of the commercial networks in the region with the intention of generating and exporting new agricultural surpluses. In addition to the south of the Indochina peninsula, Java and Sumatra experienced a massive development of cash crops. Rice cultivation dominated in the peninsula, while commercial plantations dominated in the archipelago. Throughout the 20th century, the expansion of these crops continued at the expense of the forest areas inhabited by peoples practising swidden agriculture. The demographic dynamism of the more hierarchical and organised societies led to saturation of the agricultural space. From the beginning of the 20th century, government programs such as transmigration in Indonesia organised the agricultural colonisation of the forest areas of Sumatra and Borneo by Javanese migrants. In mainland South-East Asia, the continuous expansion of the hydraulic societies brought them 'into contact' with swidden rice farmers.

2) The rise of South-East Asian agriculture: agricultural expansion and intensification

Since the 1950s, agricultural expansion has been driven by governmental programs of population resettlement and colonisation of the margins (De Koninck et al. 2003, 2005). Migratory movements associated with the expansion of agricultural pioneer fronts allowed industries to maintain, or even increase, production surpluses, turning the region into a major source of agricultural exports to the world market. The dynamics of agricultural expansion recomposed the rural territories and the relations between lowland and upland areas everywhere. The tremendous growth of the agricultural sector was associated with a widening development gap between the central irrigated basins and the marginal mountainous regions. Taking advantage of the vast areas of natural forest that were still available, agricultural expansion temporarily delayed the Malthusian spectre of a deterioration of the livelihood conditions due to population growth.

The Green Revolution marked a major shift in agricultural development patterns in South-East Asia. While rice yields had changed very little until the 1950s, rice production growth rates then exceeded those of the population growth in almost all countries of the region. The International Rice Research Institute, which was established in the Philippines in 1959, made high-yielding rice cultivars available to farmers. The combined use of improved seeds, fertilisers and pesticides of industrial origin led to a steady growth in rice production.
The adoption of short-cycle, daylength-insensitive rice cultivars helped in turn to generalise the practice of double cropping (i.e. two rice harvests per year), thanks to the development of large-scale irrigation projects (Trébuil and Hossain 2004). In addition, proactive government policies (e.g. improved transportation, storage and marketing infrastructures), economic incentives for agricultural intensification (e.g. improved access to and subsidised prices for inputs and irrigation water, generalisation of credit for agriculture, price regulations for agricultural products, provision of secured market outlets) and massive human and financial investments in agricultural research, extension and training together reduced economic risks for the farmers who adopted the new technologies. Thanks to the Green Revolution, many farmers in Asia experienced a sharp increase in their yields and revenues despite the continuous decline in the real price of cereals on the market. Rice productivity, much like that of maize, doubled or tripled depending on the region between the 1960s and 1990s. In four decades, rice production increased from 260 million to more than 600 million t. The decline in rice price benefited in the first place the poor, who tend to spend a large share of their income on the purchase of food, in both urban and rural areas. The increasing income of rural populations increased the demand for consumer goods, which contributed to the development of the whole economy. The reduction in rice price helped to feed the urban population at a lower cost and therefore to supply a cheap workforce, ensuring greater competitiveness of industrial products. Thus, the impact of the Green Revolution extended beyond the agricultural sector, and was a key driver of economic growth in South-East Asia (Dufumier 2006; De Koninck 2005). The rise of agriculture resulting from the convergence of agricultural expansion and intensification lies at the source of the great industrial transformations of the late 20th century and the emergence of the ‘Asian tigers’. South-East Asian countries experienced fast economic growth after 1986 with the development of a dynamic agricultural export industry. The emergence of this new agricultural sector was boosted by accelerated industrialisation and urbanisation, compounded by the strengthening of academic research.

The process of industrialisation in turn had a major impact on agrarian dynamics by feeding the rural exodus, by reducing population pressure in the countryside and by triggering new consumption patterns of urban populations. In the most favourable agricultural environments, farmers took up the challenge of adapting to these major societal changes through intensifying agricultural production (e.g. shifting from rice transplanting to direct sowing; mechanisation of soil tillage) and diversification of income sources thanks to opportunities of off-farm activities in peri-urban areas. Finally, agricultural successes appear inextricably linked to those of poverty reduction. The Green Revolution appeared to solve the problem of a faster population growth rate than an agricultural production growth rate, which had been perceived as a major handicap to development (Dumont 1935).
3) Upland farmers, left behind by mainstream development trends, explore alternative agricultural pathways

These processes of agricultural intensification were supported by a technocratic and prescriptive agricultural development logic. As impressive as the results are, they have been achieved in geographically limited areas which were favourable to the proposed sociotechnical models. The Green Revolution remained marginal in mountainous areas where agricultural modernisation finally gave birth to a new form of poverty (Rigg 2006). Indeed, in mountainous areas, agricultural expansion and intensive farming practices combined with population growth have increased population pressure on the slopes. Fallow periods shortened (from 10–20 years to 3–7 years) while cropping periods lengthened (from 1–2 years to 7–8 years), pushing swidden systems to the limits of their viability. The return on labour decreased gradually with increasing time spent weeding to compensate for the fertility loss caused by the shortening fallow periods. Indeed, as the fallow period helps control weed germination, land use intensification favours weed invasion. In addition, the reduced fallow biomass limits the renewal of the physical, biological and chemical properties of the soil between crop cycles. Soil fertility decreases to an ecological threshold beneath which forest cannot regenerate, and the land turns to savannah. The maintenance of soil fertility then relies on the use of organic fertilisers through crop–livestock associations, or manufactured fertilisers. However, this technological change did not take place everywhere in the uplands of South-East Asia. Instead, upland farmers explored multiple pathways to new agricultural systems.

In some places, upland rice is grown on Imperata cylindrica savannah regrowth after burning and tillage using draught animals, so as to extend the cropping period. After 20 years without fallow or fertiliser, very degraded soils are abandoned and the village is moved. Upland farmers then have to find new areas suited to their traditional practices. But following land privatisation, nomads tend either to settle in areas of fuzzy land rights, such as collective lands or reserves, with all the legal problems that this creates (Chazée 1998; Zingerli et al. 2002), or to migrate to other provinces (Déry 2004).

An alternative to migration is to terrace sloping land, which is feasible when sufficient labour or capital is available and land tenure is secured. This is usually observed (or justified) where the population density is higher than the viability threshold of swidden agriculture (~35 inhabitants / km²), so that farmers tend to prioritise return on land over return on labour. But this process of agricultural intensification is limited by water availability: the rice terraces must be irrigated. In the absence of water for irrigation, the expected economic benefit from other crops (e.g. maize, cassava) rarely justifies the initial investment in terracing. An alternative option being evaluated by IRRI would be to use new ‘aerobic rice’ cultivars, which can grow on dry terraces (Amudha et al. 2009).

An alternative to terraces for farming on sloping land involves the diversification of food production into less restrictive crops than upland rice, such as maize, cassava or potato, that can be grown with shorter fallow periods.
In the Philippines, for example, Garrity (1999) reports the widespread adoption of contour farming based on natural vegetative strips in combination with fertiliser use. Farmers adapted the practice of contour hedgerows of tree legumes, which suffered from low adoption rates because of high maintenance requirements, into a simpler, buffer-strip system as a labour-saving measure to conserve soil and sustain yields on sloping land.

Finally, access to markets has made possible the shift from subsistence agriculture to commercial farming. The range of agricultural production has greatly expanded in the uplands to include intensive annual crops, livestock and tree plantations. Hybrid maize cultivars have replaced traditional landraces, leading to a sharp yield increase and rapid expansion of cultivated area. Equally dramatic was an accelerated shift towards smallholder tree plantations. This market-driven phenomenon was facilitated by strong productivity increases in maize and other annual crops, enabling large areas to be released from food production to more profitable, and environmentally sustainable, tree-based systems. In some upland areas such as in northern Thailand, ethnic minority groups completely stopped swidden agriculture to engage in export-oriented food crops or cut flowers grown in greenhouses thanks to their proximity to an international airport.

II. Socioecological issues associated with land use transitions

1) Deforestation, land degradation and poverty

The South-East Asian agricultural development model based on the combination of territorial expansion and production intensification causes environmental problems. In the large irrigated production basins (the valleys and deltas), environmental problems relate mainly to the concentration of agricultural activities, such as the loss of biodiversity, hydrologic changes due to landscape homogenisation, and pollution caused by agrochemicals. In the uplands, deforestation, soil erosion, savannisation and biodiversity loss are the main negative impacts of agricultural expansion on fragile ecosystems (De Koninck 1998; Tomich et al. 2004; Fox 2000; Fox and Vogler 2005).

In a context of ecological fragility, arable land scarcity and endemic poverty, shifting cultivation is believed to engender deforestation and soil erosion, which undermine farming and exacerbate poverty. In turn, increased poverty drives upland populations to further intensify their pressure on natural resources to maintain a decent living. Lestrelin (2010) describes a ‘chain of degradation’ in which deforestation increases runoff and soil erosion, leading to downstream sedimentation and siltation of wetlands and reservoirs; and explains its impacts on rural development policies in the uplands, which favour forest conservation over agricultural expansion. Since the early 1990s, Thailand, Vietnam and Laos have used land-use planning and land allocation as the main regulatory instruments for reorganising local access to land resources, delineating forest conservation areas and reducing the allocation of fallow land per capita, hence limiting the extent of shifting cultivation.
The idea that shifting cultivation and population growth engender a downward spiral of land degradation and poverty in the uplands has also provided incentives for the relocation of remote communities closer to state services (e.g. schools, health centres), with better access to markets, in an attempt to lift them out of poverty. Many villages have thus been displaced from remote areas, with significant impacts on local access to land. In many places, land reforms and resettlement policies have led to agricultural land shortage and have placed upland communities in situations of extreme poverty (Castella et al. 2006a; Lestrelin et al. 2012). Combined with plantation conversion, land sale, natural population growth and unplanned immigration, swidden eradication policies have propelled and sustained the land degradation trajectory (Lestrelin and Castella 2010).

Finally, environmental issues play a central role in land-use transitions and livelihood changes. On the one hand, land degradation processes caused by deforestation have become major driving forces behind economic diversification and household differentiation. On the other hand, land degradation issue are taken up by the states in their discourses to justify poverty alleviation policies that have critical impacts on land-uses and, in turn, on land degradation processes and extent.

2) Commercial agriculture and livelihood vulnerability

Livelihood diversification can be considered as a reaction to land degradation. Some farmers maintain production by cultivating larger areas and allocating additional labour to annual crop cultivation, while other farmers shift to non-farm occupations, and thus are able to untie their livelihoods from land-related constraints. These changes have been largely promoted by government policies aimed at providing income alternatives to upland farmers. Indeed, in most upland areas of South-East Asia, poverty alleviation policies have succeeded swidden eradication policies. Depending on the socioecological context, different incentives are provided to encourage subsistence farmers to engage in commercial agriculture. Besides household-based cash crop production, with or without support from farmer associations or cooperatives, two other models of commercial agriculture have spread all over the region in recent years: large- to medium-scale land concessions leased from the state, and contract farming involving production agreements between private companies and smallholders.

Typically, agribusiness companies negotiate with the state for the acquisition of large tracts of land that are leased over several decades for the development of tree plantations. In many cases, investors can cover part of their initial expenses even before the crop enters production thanks to the extraction and sale of the timber available in the concession area before land conversion. Concessions are the preferred investment scheme for large companies, as it allows them to secure their initial investment over the long period of the lease agreement. Large-scale concessions have been a key factor of the rapid expansion for oil palm plantations, first in Malaysia since the 1980s and then in Indonesia in the 1990s, and more recently, and to a lesser extent, in Thailand and neighbouring countries (De Koninck et al. 2012).
This model has developed rapidly since the 2000s, driven by massive investments by multinational corporations in agricultural commodities, and by incentives provided by governments to favour foreign direct investments. While rubber or coffee, for example, used to be produced mostly by smallholders in Thailand, Indonesia and more recently Vietnam, the recent expansion of these tree crops into marginal areas, such as Laos, Myanmar or Cambodia, increasingly takes the form of large private concessions (Fox and Castella 2013). Despite political discourse stressing the positive impact of foreign investment on the adoption of intensive and ‘modern’ cropping practices by upland farmers, the rapid expansion of tree plantation concessions has two major negative consequences for local livelihoods. The first is related to disputes with smallholders being evicted from their land without proper compensation; many land conflicts have been reported recently in Cambodia and Laos, for example (Baird 2011; Kenney-Lazar 2012). The second is that farmers are gradually turned into daily wage workers, with negative consequences for their livelihoods and for the availability of family labour for smallholder agriculture. This lack of labour on large commercial farms is often compensated for by massive migration of workers from poorer areas of the country or from neighbouring countries. The generalisation of this new class of poor landless agricultural workers, often illegal migrants, has created many tensions in places where integration into the local society is problematic.

An alternative to land concessions that allows private companies to use local labour is to develop contract-farming schemes. In the nucleus estate model, smallholder farms around the concession are contracted so as to increase the throughput for the processing plant, without the need to acquire more land. The estate plantation also serves as a trial and demonstration farm for private agricultural extension agents to introduce to ‘satellite’ smallholder farmers the management techniques of the crop. Nucleus estates have often been used in connection with resettlement or transmigration schemes, such as in Indonesia for oil palm and other tree crops. Contract farming can be structured in a variety of ways depending on the crop, the objectives and resources of the company and the experience of the farmers. In Thailand, for example, contract farming has long been used by the sugar industry. Quotas are distributed by the mills to individual farmers or production groups at the beginning of each growing season, and quality is tightly controlled. The government regulates prices, promotes and manages technical research centres, and encourages producer associations. Such schemes are generally associated with tobacco, sugarcane and bananas and with tree crops such as coffee, tea, cocoa and rubber, but can also be used for fresh vegetables and fruits, poultry, pork and dairy production. Wherever governments do not allocate state land to investors and farmers do not have any capital to invest in the conversion to commercial agriculture, so-called ‘2+3 contract farming’ arrangements have spread rapidly in recent years. Under this arrangement, rubber smallholders in Laos provide land and labour (2 factors), and private investors provide seedlings, herbicides and equipment (3 factors), in addition to technical expertise and market outlets.
Depending on the level of financial investment by investors, on their monitoring capacity and on relations with government extension workers, this contract farming model involves a variable risk of default by both investor and farmer.

Driven by the increasing demand by China for agricultural commodities and by large investments by international corporations, the boom of commercial crops has had a tremendous impact on local livelihoods in the last decade. While specialising in a limited number of commodities, growers have become more vulnerable to price fluctuations and are dependent on a larger number of intermediaries. They are also more indebted than before. As inputs are often provided on credit, households find themselves in debt when yields or prices fail to reach the expected levels. Rapid economic differentiation has enlarged the gap between rich lowland areas and marginal uplands, but at the same time it has also increased economic inequalities between upland farmers who were able to seize investment opportunities, with the enormous risks involved, and the late adopters or landless workers.

3) Territorialisation of the upland margins and landscape governance issues

The socioecological changes described above came with profound transformations of the agrarian landscape. Revisiting the regional historical pathways of land use change, we identified a succession of 3 state territorialisation processes that are common to most South-East Asian countries.

Securing the margins and exploiting abundant natural resources

Early upland development policies were aimed at securing the territorial ‘margins’ of the countries, initially to avoid political unrest during colonial times, and later during the Indochina war, when opponents were hiding in the dense remote forests. Thailand, Indonesia and Vietnam asserted their political control over remote and potentially subversive upland populations by colonising the ‘margins’ through state-sponsored agricultural expansion (De Koninck 2006). Roads opened into the forest brought in first timber logging companies, and then later settlers who migrated from the lowlands to expand cash crops into upland areas formerly dominated by swidden agriculture. This happened for example in north-eastern Thailand in the 1960s, and then in Indonesia with the transmigration policy supporting the spread of oil palm into remote forested areas, and more recently with massive internal migrations organised to support the expansion of coffee plantations in the central plateaux of Vietnam. These population movements brought state institutions and dominant lowland populations (e.g. Kinh ethnics) to the uplands. In Laos, characterised by a rough terrain and limited state resources, upland populations were also moved down the hills through village resettlement, officially to provide them with better access to state services (e.g. schools, health centres), but also to establish tighter control over their movements and their access to natural resources (Scott 1998; De Koninck 2006; Baird and Shoemaker 2007; Lestrelin et al. 2012). These common objectives of securing the national territory, turning subsistence farmers into taxpayers, integrating upland ethnic minorities into the national identity and reinforcing state control over key resources led to the rapid expansion of commercial agriculture, pushing the deforestation fronts to the periphery of the national territories.
Stopping land degradation and rationalising land use

During the 1990s, new territorialisation policies emerged in reaction to the rapid resource depletion that occurred during the previous period. Logging bans were imposed in Thailand, Vietnam and the Philippines after dramatic landslides and flash floods. More generally, policymakers became conscious that the natural resources that they had used to support rapid economic development were limited. International development agencies spread sustainable development discourses and conditioned their support to increased environmental awareness. New upland policies consisted in rationalising land use through land zoning and land use planning. Scientific expertise replaced national integration as the main instrument for developing the country (Lestrelin et al. 2012). Forests were classified according to their dedicated purpose (conservation, protection or production), and land suitability maps were established with the support of international experts to define the best use of all upland areas (i.e. forestry, agriculture or livestock). In most South-East Asian countries, national protected areas were created in the 1990s. In addition, a large range of land management and planning approaches were tested and applied at the micro and meso levels (e.g. community-based natural resource management, integrated catchment management, upland–lowland integrated planning projects), while master plans were developed at the national level. While R&D projects achieved interesting results as instruments for change, their influence was gradually reduced as private sector investments promoted by the governments took off.

Turning land into capital

Whereas Malaysia had granted land concessions to oil palm companies for several decades, other countries such as Thailand and Indonesia granted concessions at the large scale only in the 1990s, and private Chinese and Vietnamese investments in Laos and Cambodia boomed in the 2000s. Granting land concessions has become a key policy instrument to increase land productivity of supposedly underutilised uplands while achieving other goals such as introducing modern technologies into remote areas and providing stable employment to rural populations. With the ‘green neoliberal’ development models put forward by donors such as the World Bank and the Asian Development Bank (Goldman 2001) and a growing demand from the (mainly foreign) private sector to gain access to the country’s land and natural wealth, market forces have become a key instrument for facilitating sustainable development (Lestrelin et al. 2012). Consequently, the focus of land use planning has shifted from ‘rationalising’ existing land uses to identifying ‘empty’ space or freeing space for the development of large-scale mining, hydropower, plantation and agribusiness concessions. Despite commendable efforts made to harmonise land use plans across scales, the granting of concessions at a rapid pace in the absence of tight monitoring on the ground has led to many disputes and is the source of many land conflicts that have arisen in recent years.
In Indonesia and Laos, for example, the state decentralisation process allowed districts or provinces to grant land concessions. But the limited coordination between administrative levels and between line agencies ended up allocating the same pieces of land several times to different users, creating confusion and tensions over access to natural resources.

With the rapid integration of upland areas into the world market, multinational agribusiness companies are gradually replacing the states in driving land use transitions. Despite the high contribution of agriculture to economic development, states have gradually disengaged from agricultural production, leaving the management of agricultural frontiers to multinational companies (De Koninck et al. 2012). Relations between upland dwellers and agribusiness companies are multiple and complex. They depend on the companies, the crops, state regulations and how different stakeholders can negotiate local arrangements. In some cases, local communities manage to benefit from opportunities offered by companies, while in other cases, land-grabbing practices deprive smallholders of their land without proper compensation. Between these two extremes, smallholder agriculture has evolved continuously to adapt to successive land use policies, land degradation and the emergence of new actors with competing development claims. Through these successive reconfigurations, smallholders have demonstrated their capacity to innovate.

III. What are the prospects for conservation agriculture?

Today, there is a broad consensus about the necessity to buffer the negative consequences of the agrarian transition and to ensure the sustainability of smallholder-based agriculture. To address problem of land degradation, in 2005, the government of Laos issued a decree that generalises the use of conservation agriculture (CA) across the country. In Indonesia, complex agroforests that retain about half of the biodiversity of the dense natural forests and that connect forest patches to each other to create conservation corridors are under threat from the rapid expansion of oil palm plantations (Feintrenie and Levang 2009). Different payments for environmental schemes have been designed and tested with limited success to prevent this land use conversion (Feintrenie et al. 2010). In South-East Asia, as around the world, the international scientific community is en route to a ‘doubly-green revolution’, i.e. agriculture that is both productive and environmentally friendly (Conway 1997). It involves a shift from a logic of controlling nature to working with ecosystems: playing with the diversity of farming systems, not trying to homogenise the fields and the people (Griffon and Weber 1996). The idea that a second Green Revolution cannot result, like the first, from a simple transfer of technology has made its way in the scientific community.

The ability to influence the agrarian transition towards sustainable development is one of the major challenges of international research (Young et al. 2006).
Many communities are mobilised worldwide to give the scientific basis for this new, intentional transition and to put it into practice on the ground. Indeed, the uncertainty inherent in rapidly changing socioecological environments forces scientists to rethink and adapt their research practices. Far from controlling transformations, they can at best influence their direction and speed. Beyond a better understanding of the natural and human environments, or the design of new technologies, researchers are asked to define new development pathways and new modes of governance towards sustainable development as defined by the Millennium Development Goals (Raskin et al. 2002).

1) Adapting innovations to the coexistence of intensive and extensive agricultural systems

In South-East Asia, agricultural expansion and intensification are interacting at multiple scales (village, district, region) between lowlands and uplands, paddies and swiddens, central and peripheral spheres of power. The same types of relations between lowland and upland populations as those described at the level of upland villages exists between irrigated areas of Asian mega-deltas (e.g. Chao Phraya in Thailand, Irrawaddy in Myanmar, Red and Mekong rivers in Vietnam) and marginal upland areas that surround them. Historically the same processes of agricultural expansion and intensification have been at work between ‘lowlands–paddies–centre’ and ‘uplands–swidden–periphery’ at all scales: village, commune, district, province, country and South-East Asia. All over Asia, intensification of the lowlands, first through labour and then through capital (through mechanisation and chemical inputs), has clearly contributed to improved farm productivity. Encouraged by the individual allocation of forest lands, this process of lowland intensification decreased the pressure on the slopes for families who had access to lowland fields (Castella et al. 2006a). If swidden systems persist today it is because some farmers do not have access to fertile lowlands. Among them are ethnic minorities, but also young generations of farmers who have not inherited enough lowland from their parents or who have not managed to engage in off-farm activities. Beyond land issues, the reasons for the persistence of swidden agriculture despite population densities exceeding the viability threshold of these systems are to be found in the complex interactions between intensive and extensive systems at local scales.

In fragile upland ecosystems, extensive agricultural practices spread the risk of crop failure and form part of risk management strategies. Furthermore, the different modes of fertility reproduction interact dynamically at the local scale, through biomass flows or through livestock movements between cultivated and non-cultivated parts of the landscape. In addition, non-agricultural functions of fallows (e.g. forage, timber, medicinal plants, land ownership demarcation) contribute significantly to swidden persistence despite increasing land pressure. Finally, pathways towards ‘sustainable agriculture’ should remain compatible with the persistence of extensive systems, as the coexistence of extensive and intensive cultivation practices is essential to the sustainability of the whole system.
2) Identifying windows of opportunity in space and time

Beyond sustained efforts to increase the system’s resilience or its ability to adapt to unavoidable changes (e.g. by maintaining the diversity of farming systems and practices), major transitions can be triggered by innovations that arrive at the right time, when the conditions for success are met; that coincide with a window of opportunity sometimes limited in space and time. Steering the transition towards desirable futures then consists of assessing whether the context is favourable to the adoption and diffusion of the innovation and creating the conditions for change to happen (Kemp et al. 1998).

In maize production areas of Laos, for example, Lestrelin and Castella (2011) identified two windows of opportunity for CA: First, at an early stage of the commoditisation and intensification of agriculture, when swidden agriculture is no longer an option and upland farmers are in search of low-input alternative practices; dissemination efforts and technical support to CA may allow smallholders to engage in more sustainable practices. Second, at the stage of land degradation and diversification from intensive tillage–based cropping systems; CA can easily become an economically and ecologically sound alternative. The concept of a socioecological niche for innovation (Giller et al. 2009) helps define areas where -and times when- particular types of technical innovations are more likely to be adopted by smallholders. Soil erosion, access to farm inputs and markets and the presence of smallholders with sufficient land, labour and capital are key criteria for identifying these niches. Physical accessibility (i.e. distance to markets or decision centres) and social accessibility (i.e. relative marginalisation of social groups depending on their ethnicity, gender or religion) also distribute development opportunities in space and the capacity of smallholders to adapt to changes (Castella et al. 2005).

Regularities can also be identified in the complex transition processes in the form of trajectories that repeat themselves in space with a longer or shorter time-lag. For example, phenomena that have been described in Thailand, Indonesia and other parts of the world affected by the opening of roads in forested uplands, or land privatisation by agribusiness investors in a context of fuzzy land tenure, can be identified in Laos today. Lessons can be drawn from the past experiences of neighbouring countries to adapt intervention mechanisms (e.g. environmental regulations, payments for environmental services, eco-certification) to the particular context of each area in relation to its stage in the socioecological transformation pathway.

3) Connecting actor-networks and negotiating innovation pathways

Transitions can also be initiated by tensions or transformations happening at higher levels, as for example the negative externalities of intensive agriculture on the environment (e.g. land degradation, pollution), massive migrations or political reforms. Environmental activists seek to transform the sociotechnical systems by combining bottom-up pilot experiments with, for example, organic production or renewable energy, and top-down advocacy approaches, for example, anti-globalisation movements against multinational agri-food business and agrochemical industries or anti-GMO campaigns.
Changes often occur through the reorganisation of actor-networks in reaction to situations deemed unacceptable (e.g. land grabbing) or in contexts of collective actions aimed at designing more desirable futures (e.g. Landcare organisations in Australia and the Philippines). The linkages between local and regional drivers of the transition are provided by multiple actor-networks: research and extension networks define recommendation domains for innovations; transport networks determine accessibility gradients; commercial networks define market chains and outlets; and sociotechnical networks facilitate communication, access to information and credit. Network structure and density determine the capacity of the socioecological systems to adapt to endogenous or exogenous factors of change. Indeed, poverty and vulnerability are usually correlated with marginal positions in a social network. Therefore, opportunities should be provided to vulnerable and disadvantaged groups to make connections and build alliances that enable them to solve their own problems.

Moreover, inflections or bifurcations in land use trajectories are systematically linked with some kind of negotiation among stakeholders, be it implementation of a new policy or granting a concession. The quality of the negotiation then determines to a large extent the type of trajectory that will unfold and who will be the winners or losers of the negotiated changes. In turn, the quality of the negotiation is determined to a large extent by who takes part, the level and quality of information held by each stakeholder, and the power relations that may allow some stakeholder groups to impose their views on others. Improving the quality of the negotiation can certainly help influence pathways of changes.

Experience in Vietnam illustrates such negotiation process in the context of the diffusion of CA techniques (Castella et al. 2006b). The adoption of cropping systems with cover crops was possible only as part of the concerted management of forage resources across the village. Several scenarios were discussed with a group of farmers selected for their representativeness of the different types of land use found in the village. By facilitating common understanding of problems related to crop–livestock interactions and providing visualisation and simulation support, researchers engaged local communities in negotiating alternative scenarios that could be explored collectively. Through active engagement of local actors in a collective learning process, local dynamics of change then appear as internally negotiated forms of the technical or organisational innovations that are proposed by outsiders (e.g. extension agents, researchers, private companies).

Throughout South-East Asia, decentralisation policies provide a legal framework to engage local communities in public consultations and to increase the legitimacy of local actors as forces for proposition and negotiation. Development projects promote community management of renewable resources and participatory approaches (Neef 2005). But they often struggle to move away from conventional discourse and to put their recommendations into practice on the ground.

In short, the institutional context is favourable for the implementation of a concerted management of natural resources and territories, but methods are still lacking, or are not used by extension agents on a significant scale.
References


Land abandonment in middle hills of Nepal: an opportunity to reinvigorate agroforestry to improve food security

Krishna P. Paudel*1, Dipankar Dahal1, Sarada Thapa3 and Sujata Tamang4

1 Food and Sustainable Agriculture Initiative, Forest Action Nepal, PO Box 12207, Kathmandu, Nepal

*Corresponding author: krishna@forestaction.org

This paper1 explores the extent of agricultural land abandonment and its implications for agro-forestry in the middle hills of Nepal. It is based on a recent field study carried out in 4 districts of the middle hills which sought to identify and understand the context and consequences of agricultural land abandonment, in particular the constraints and opportunities in relation to food security and livelihoods of rural communities.

We used both qualitative and quantitative methods of inquiry, using a participatory rural appraisal in 4 villages, through focus group discussions, case histories and a survey of 200 households, to investigate rates of migration, food security and accessibility.

Many ecological, socioeconomic and cultural factors influence land use change across the study sites. The mountain environment is biophysically fragile and vulnerable, with highly fragmented and diversified farmland, which makes it difficult to adopt modern, market-oriented farming practices. In addition, climate change impacts are visible as changed rainfall patterns, disappearing springs and species shifts due to temperature rise, all lowering the productivity of the region.

The commercialisation of agriculture through mechanisation and high-input intensive farming has made small-scale subsistence farming less profitable than before. Socioeconomic factors such as landlessness, decreasing access to productive natural resources, low returns on labour and other investments, and increasing demand for cash to pay for health, education and other social services create disincentives to farming communities to continue farming in the hills.

Culturally, intensive hill farming is no longer seen as a viable option, and many young farmers are abandoning their farms. In addition, the discourse of men growing up in the hills has encouraged a view of villages as being traditional places to be left, and of urban areas to be desired.

1 This paper is based on a field study of abandoned agricultural land in the middle hills of Nepal commissioned by ICRAF/ACIAR. The authors have completed the field work and are now analysing the data.
The remittance economy, associated with the emigration of economically active labour, mainly male, to seek urban and overseas employment, has become the most powerful force transforming rural life and livelihoods. In the last 10 years a massive emigration of rural youth has dramatically changed the rural landscape of the middle hills of Nepal (Paudel and Adhikari 2010).

A large proportion of the household cash income is spent on food, clothing and consumables. Our field study shows that 82% of the remittance is spent on daily consumption, followed by repayment of loans (7%), acquiring property, education and building capital. This distribution highlights the severity of food production at the local level.

Emigration has catalysed changes in production, productivity and gender roles in production, and has led to the adoption of less intensive farming with fewer crops in the cropping cycle, lowered organic inputs and less land preparation. The net result is the abandonment of farmland.

In the study area, 30% to 40% of private land has been abandoned, mainly by households whose members have left. The rate of abandonment was 20% in the 2000s and <10% in the 1990s (Thapa 2001; Khanal 2002; Gautam 2004). This land abandonment has a tremendous impact on food security and local livelihoods in areas already suffering from mass poverty and food deficits. It also has several negative consequences for the stability of terraced hill slopes.

Although 80% of households are involved in agriculture, with 78.5% of the workforce (89.6% of women), agriculture generates only 1/3 of total GDP (ADB 2011). In 2010, 55.2% of farm households owned <0.5 ha each (CBS 2011). In addition, out of 56.6 million households, 4.25 million farming households are landless, of which half have no land even for housing. The rate of absolute poverty ranges from Nepal’s estimate of 25% to the World Bank’s estimate of 33.9%. Rural households in the middle hills derive around half of their livelihood from non-farm income (33%) and remittance (16%). However, the poor and marginalised households receive almost no remittance.

The low prospects for livelihood diversification and the weak non-farm rural economy indicates a need to invest in agriculture despite the low returns. Agriculture is the only available livelihood strategy for millions of households. The current dynamics of agrarian transformation, particularly land abandonment, present opportunities to bring marginal fallow private land and community-managed forests into agroforestry practice. The labour scarcity favours the use of less-labour-intensive horticulture-based agroforestry on private land. Increasing demand for fruits, nuts and other high-value crops has also created market opportunities for agroforestry products.

Therefore, agroforestry, as a proven, sustainable agroecological approach, could be introduced to address climate change threats and increase food security for the poor and marginalised. However, efforts must integrate farming with forestry and productivity with sustainability and equity of resources, and develop credible socioeconomic models that include resource access and entrepreneurship.
Keywords

Remittance economy, rural landscape

References


Bibliography


IFAD 2012. IFAD’s Adoption for Smallholder Agriculture Program (ASAP), Rome: International Fund of Development.


Determinants of farmers’ decision to continue farming the rice terraces of Hungduan

Ma. Larissa Lelu P. Gata*1, Margaret M. Calderon1

1 College of Forestry and Natural Resources, University of the Philippines, Los Baños

*Corresponding author: mllcp.gata@gmail.com

In 1995, UNESCO declared the Ifugao rice terraces, in the Philippines, a World Heritage Site. One of the challenges to the efforts to protect and preserve this cultural legacy is the weakening interest among the Ifugao people in maintaining their terraces. This loss of interest not only endangers the remaining traditional farming system, but also poses a threat to the sociocultural fabric among the Ifugao people, whose main source of livelihood depends on it and whose identity is tied with it.

Our group conducted 2 research projects to investigate how to conserve surviving traditional agricultural systems (Calderon et al. 2009, 2011). The projects focused on men as head of household. The men expressed no intention of abandoning their traditional rice terrace farming anytime soon. Those who had already abandoned it said they could be lured back by labour subsidies from the government and repair of the irrigation systems.

As Ifugao women play key roles in maintaining rice terrace farming, we returned to this research site, specifically in the municipality of Hungduan, to survey men and women.

We set ourselves 3 questions: Is there a significant difference in the proportions of male and female farmers abandoning rice terrace farming? What are the key socioeconomic and biophysical factors that influence the farmers’ decision to abandon rice terrace farming? What is the likelihood that the farmers will abandon rice terrace farming in the future?

We explored the significance of gender in determining a decision to abandon among Ifugao farmer-couples. By exploring the gender relationships within a traditional farming system, we identified the contributions of female farmers that are not readily captured in the usual quantitative analyses. We present some innovations in social research using mixed methods to unearth relationships that are not usually obvious when either qualitative or quantitative methods are used.

We interviewed male and female farmers from 35 households that were chosen randomly from the previous research population. We used the previous questionnaire with some revisions to lend itself to gender analysis. The survey gathered information on respondents’ farming practices, water supply, labour availability, costs and returns from farming, and socioeconomic condition.
We generated gender-disaggregated data by interviewing men and women separately on questions soliciting opinions and personal beliefs, and together on household profile. The results were analysed quantitatively to determine the statistical significance of abandonment decisions. Tests of proportion (Z-test) were used to determine whether the proportions of men and women who decided to abandon rice terrace farming were significantly different.

Tests of association (Cramér’s V and \( \psi \) coefficients) of the determinants of the decision to abandon rice terrace farming were done to determine the degree of association of statistically significant factors (\( \alpha = 5\% \)). Logistic regression was used to predict the likelihood of abandonment of rice terrace farming in the future. We also qualitatively analysed access, control and participation in the decision-making processes among couples.

Hypothesis 1, that there is no difference in the decision of male and female farmers to abandon rice terrace farming, is accepted. The lack of a significance difference may be due to the difficulty of getting a ‘yes’ response, because rice terrace farming is culturally embedded in the people’s survival as households and communities (UNESCO 2008; Perera 2009; Gonzales 2001).

Hypothesis 2, that socioeconomic and biophysical factors such as gender, age, income, education, years of farming, size of farms, farm ownership and perception of labour availability do not influence the decision of farmers to abandon rice terrace farming in the future, is rejected. Primary occupation, education and farm ownership had a strong association with the decision to abandon rice terrace framing in the future. Secondary occupation, locality, manner of acquisition, sufficiency of water supply during the dry season, duration of fallow period and availability of funds for terrace maintenance had a moderate association. Gender and age were not associated.

Hypothesis 3, that key socioeconomic and biophysical factors do not affect the likelihood of abandonment, is rejected. Among other things, gender and age were statistically significant in the likelihood of abandoning rice terrace farming in the future, unlike in the first two hypotheses. The odds that women will abandon rice terrace farming compared with men increase 4x; while for every unit increase in age, the odds of abandoning rice terrace farming increase 9x.

The large number of key determinants highlights the fact that a decision to abandon rice terrace farming results from the composite reality of the household setting.

Including the gender dimension enriches the analysis and provides more information to better explain the decisions by farmers. Had we assumed that rice terrace farming is solely the men’s domain, we could have not examined the intricacy of the household division of labour based on gender. We could not have shown how female farmers are engaged in planting, weeding, cleaning and harvesting while men work in the maintenance of terrace walls.
The lack of funds for terrace repair and maintenance burdens not only the men, but also the women, who are responsible for the bulk of the production activities. Although gender was not a significant factor in the current decision of farmers to abandon rice terrace farming, women are more likely than men to decide to abandon it in the future.

We make the following key policy recommendations:
1. In general, there should be a deliberate effort to integrate gender in project design, implementation and evaluation at all levels of R&D efforts, especially in farming systems.
2. The key to gender-sensitive studies and developmental efforts is to base actions and policies on gender-disaggregated data.
3. Incorporating gender analysis entails additional cost. Thus, we should be strategic and organised in identifying research questions that need gender-disaggregated data.

Keywords
Terracing, farming, Ifugao, abandonment, conservation

References

Bibliography
Alternative upland farming system under different climate scenarios

Linda M. Peñalba*,1, Felino P. Lansigan2, Dulce D. Elazegui1, Francis John F. Faderogao1

1 College of Public Affairs and Development, University of the Philippines, Los Baños
2 College of Arts and Sciences, University of the Philippines, Los Baños

*Corresponding author: lmpenalba@gmail.com

The Philippine uplands contribute significantly to food production. About 5 million hectares is under cultivation, but much of it has been degraded, and about 70% has soil erosion problems (Cruz et al. 2010).

Intensification of upland cultivation is expected because of high population pressure and conversion of lowland areas due to urban expansion. This is expected to exacerbate upland degradation, since conservation agriculture (CA) is not yet widely practised, and weather events are expected to intensify.

Currently, upland farmers practise row cropping and ploughing along the slopes. No-tillage or zero tillage is not a popular practice in the uplands, and farmers are not convinced that high productivity is possible without tillage. Farmers till to place the seeds into the soil, to control weeds on the large scale, to promote aeration of the soil, and to promote the mineralisation and release of nutrients from soil organic matter.

Typhoons are the most destructive weathers events experienced by Philippine farmers. When they arrive in May, at the end of the dry season, they cause severe erosion, because the soil is exposed and powdery. If current practices are not modified, the combined effect of temperature increase and rainfall increase will worsen soil erosion. These events already cause massive soil erosion and degradation, which result in low farm productivity. For example, more than 350 large dams have become silted, reducing irrigation efficiency and loss of 20% to 30% of irrigated lands (Cruz et al. 2010).

Climate change scenarios are useful in characterising future climate risks and for evaluating the performance of adaptation options, but most scenarios operate at the national or greater scale. These projected climate scenarios have to be downscaled to determine more precisely the appropriate local response actions. Such downscaled projections can be used by planners in designing innovative CA technologies for the Philippine uplands and in planning R&D to improve the current upland farming practices and climate change adaptation in the country.
We present projected climate change scenarios in selected Philippine uplands in 2020, 2050 and 2080; their potential impacts on rice yield if current practices continue; and recommended alternatives to achieve food security and sustainability.

The results can be used by local planners in preparing local plans to mitigate social, economic and environmental impacts of climate variability and extremes on a specific sector.

In a SUMERNET- and CDKN-funded project on climate change, food security and livelihoods of small-scale farmers, we collected data on rice yields and production practices in the Philippine provinces of Tarlac and Pangasinan through key informant interviews, focus group discussions and interviews with rice farmers.

Daily rainfall and temperature data from 1971 to 2000 were collected from the national weather bureau. A statistical downscaling technique using the Coupled Global Climate Model (CGCM3) was used to generate climate scenarios in 2020, 2050 and 2080.

The potential impacts on rice yields were determined by using the Decision Support System for Agrotechnology Transfer crop simulation model, which integrated generated daily weather data with physiochemical properties of soil, rice crop management practices and genetic coefficients of standard rice cultivars to simulate the growth and development of the crop. There will be not much difference in rainfall patterns between the baseline, 2020, 2050 and 2080 scenarios (Table 1).

However, the amount of rainfall is expected to increase considerably from 300 mm to 400 mm in June, from 500 mm to 800 mm in July, and from 300 mm to 400 mm in September. These changes in rainfall distribution might have serious effects on rice yield, since these months coincide with critical periods in the rice production cycle.

Table 1. Projected climate scenarios for Tarlac and Pangasinan provinces.

<table>
<thead>
<tr>
<th>Year</th>
<th>Temperature (°C)</th>
<th>Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tarlac</td>
<td>Pangasinan</td>
</tr>
<tr>
<td>Baseline</td>
<td>27.15*</td>
<td>27.85*</td>
</tr>
<tr>
<td>Percentage change</td>
<td>-0.95</td>
<td>0.0044</td>
</tr>
<tr>
<td>2020</td>
<td>2.59</td>
<td>0.0475</td>
</tr>
<tr>
<td>2050</td>
<td>2.59</td>
<td>0.0048</td>
</tr>
<tr>
<td>2080</td>
<td>2.59</td>
<td>0.0048</td>
</tr>
</tbody>
</table>

*Average temperature.

The combined effects of the increases in temperature and rainfall on rice production vary with the time period, location, cropping season and planting schedule. In general, yield will increase in both provinces (Table 2).
Table 2. Effect of projected climate scenarios on upland rice yields.

<table>
<thead>
<tr>
<th>Year</th>
<th>Tarlac</th>
<th>Pangasinan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline*</td>
<td>5387.81</td>
<td>6963.6</td>
</tr>
<tr>
<td><strong>Percentage change</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>15.9</td>
<td>5.36</td>
</tr>
<tr>
<td>2050</td>
<td>48.4</td>
<td>7.53</td>
</tr>
<tr>
<td>2080</td>
<td>−34.95</td>
<td>6.2</td>
</tr>
</tbody>
</table>

*Actual yields based on interviews with rice farmers.

To take advantage of the expected changes in water supply during critical plant growth periods, we recommend:

- adjustment of the cropping calendar to avoid water stress during the critical months
- crop rotation and diversification to control pests and diseases
- construction of small reservoirs and bunds to capture rainwater for use during the dry months
- zero-tillage for more effective water infiltration and to prevent soil erosion and degradation
- use of appropriate cultivars such as drought-resistant or submergence-tolerant ones
- farmers' education to improve the social acceptability of CA technologies and to help farmers make informed decisions on technologies they can adopt in consideration of the projected climate changes.

Further research should estimate soil losses that projected climate change may cause, study what characteristics of rice crop should be further developed to adapt to projected climate conditions, and study the social, economic and environmental impacts of various CA technologies and the social acceptability of innovative farming practices.

**Keywords**

Downscaled climate scenario, Philippines, Tarlac, Pangasinan

**References**

Adaptation to climate change by farmers in uplands of Gunung Kidul district, Indonesia

Irham*1, Arini Wahyu Utami1, Osamu Saito2, Hideyuki Mohri2

1 Department of Agricultural Socioeconomics, Faculty of Agriculture, Gadjah Mada University, Jl. Flora, Bulaksumur, Yogyakarta 55281, Indonesia
2 Institute for Sustainability and Peace, United Nations University, 5-53-70, Jingumae, Shibuyaku, Tokyo 150-8925, Japan

*Corresponding author: irhamsec2000@yahoo.com

Climate change has serious consequences, especially for developing countries, which depend strongly on natural resources for food, water and shelter (FAO 2010). Climate change is experienced as slow changes in mean climatic conditions, increased interannual and seasonal variability and increased frequency of extreme events, and rapid change causing catastrophic shifts in ecosystems (Tomkins and Adger 2004). The effects of each manifestation of climate change can bring opportunities to some communities and problems to others. Different societies respond to the consequences of climate change according to different patterns of adaptability. Different forms of local adaptation offer examples of how societies innovate in coping with threat, and the interactions between ecosystems and humans become key issues to identify and develop (Takeuchi 2012; Irham 2012).

There is a strong relation between adaptation, resilience and sustainability. Resilience is the ability to persist and adapt in order to achieve sustainability. But resilience and sustainability need preemptive action on emerging risks, to avoid vulnerability and to provide ecological integrity (Hahn et al. 2009). Enhancing resilience means increasing communities’ adaptability while reducing vulnerability, risk and uncertainty. Acceleration of economic development has a strong relation with the increase of such problems.

Our experience from the field shows that unfavourable rural areas provide more opportunities to find key lessons for resilience than favourable areas, where economic development can undermine traditional wisdom. Our study in the less favourable upland area in Gunung Kidul district, Yogyakarta, Indonesia, allowed us to test this hypothesis.

Many studies have examined the impact of climate change on biological production, water availability, temperature and other factors. But few studies have examined how traditional societies understand climate change and how they are coping with the consequences (Olsson 2003; Takeuchi 2012). This study will contribute to understanding how climate change is defined from different perspectives by examining farmers’ experience of climate change in relation to their farming activities.
The objectives of this study were (1) to understand farmers’ perceptions of climate change in the upland area, (2) to see how the farmers adapt to cope with climate change and (3) to analyse the influence of their socioeconomic situation on their adaptation strategies.

The study was conducted in Jati hamlet, Giri Cahyo village, in an upland area of Gunung Kidul district. Jati lies 30-40 km from the nearest city, making it difficult for villagers to commute for work. This separation of Jati from the outside world has likely contributed to the persistence of older types of labour institutions. The farmers depend entirely on rainfall, and can grow only 1 upland crop a year.

We interviewed 35 farmers on our 3 objectives. We used cross-tab analysis to analyse perceptions on climate change and adaptation strategies, and regression to analyse the influence of socioeconomic situation on adaptation strategies.

Most of the farmers had no idea about global warming, but they had experienced climate change during the last 20 years, such as in increases in temperature, unstable rainfall and unpredictable rainy and dry seasons. Production has fluctuated more, and sometimes harvests have failed. Pest outbreaks have also occurred. The farmers have responded by adjusting to an earlier rainy season, stocking up on food, rotating crops and using organic manure. Their level of education and number of family members had a positive influence on their adaptation strategy.

**Keywords**

Farmers’ perception, sustainability, resilience

**References**


Hahn MB, Riederer AM, Foster SO. 2009. The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change - a case study in Mozambique.


Agroforestry practices in changing rural landscapes in Nepal: the de-manning of agricultural work, climate change and food security

Sujata Tamang*1 and Krishna P. Paudel1

1Food and Sustainable Agriculture Initiative, Forest Action, Nepal

*Corresponding author: sujutamang@gmail.com

The objective of this study was to understand the causes and consequences of the de-manning of agricultural work and its impact on food security in the context of changing social and environmental dynamics, particularly the emigration of men from rural villages and the effects of climate change. This paper is based on field studies carried out in 4 districts in the middle hills of Nepal. We used both qualitative and quantitative methods, using case studies, focus group discussions and key informant interviews, followed by a survey of more than 200 households.

The results reveal that rural Nepal is going through a complex process of socioeconomic transition. One change is the massive emigration of young men from rural areas, leaving women to do the agricultural work. Population growth, decreasing access to productive natural resources, low returns on labour and other investments, and increasing demand for cash to pay for health, education and other social services have triggered the mobilisation and brought changes in rural dynamics across the country (Paudel and Adhikari 2010).

The remittance economy, associated with the emigration of economically active labour, mainly male, to seek urban and overseas employment, has become the most powerful force transforming rural life and livelihoods. A large proportion of the household cash income is spent on food, clothing and consumables. Remittance is now the most powerful driver in changing the rural landscape, followed by infrastructure development and improved access to markets, which have encouraged monetisation, consumerism and urbanisation (Seddon et al. 1998).

Both social and production relations have changed at the household level. For example, the proportion of female-headed households has increased from 14% in 2009 to 22.1% in 2012. Production and productivity have also been affected: since labour is now scarce in rural areas, farmers have adopted less intensive farming with fewer crops in the cropping cycle, and farm production has decreased. In the study villages, 25% to 30% of farmland has been abandoned in the last 20 years. In addition, the costs of essential inputs have increased manyfold; farmers have to spend an increasing share of their income to purchase inputs, which reduces production.
These changes to the overall production relations and to farming systems have implications for food security. Primarily, farming is no longer viewed as an honourable and worthwhile occupation. The discourse of men growing up in the hills has encouraged a view of villages as being traditional places to be left, and of urban areas to be desired.

The ideal model of masculinity is now shaped by contemporary views of consumption and modernity. Traditional farming is not consistent with this view and has much less appeal to the younger generation (Sharma 2011).

Further, recent consequences of climate change, particularly unpredictable rainfall, failure of common crops and new pests and diseases, have prompted farmers to investigate economically viable and ecologically sustainable farming system. This situation suggests that our agroecological practices need to be changed immediately to climate-smart, resilient approaches (FAO 2010; IFAD 2012).

These changes have resulted in considerable food scarcity and severe food insecurity, particularly among the poor. Food insecurity among the poor can be attributed to limited access to productive land, lack of rural non-farm employment, low wages and little access to the remittance economy.

This situation suggests that there has been a rapid change in the rural landscape, with changing socioeconomic and ecological dynamics. It is particularly visible in the middle hills of Nepal, which are characterised by environmental fragility, poorly productive subsistence agriculture and limited opportunities for non-farm economic activities. At the same time, there are significant shifts taking place from traditional, informal, local agricultural institutions to modern, formal, bureaucratic institutions, often bringing state and market actors into the institutional landscape (Thapa 2001).

One of the significant and obvious changes in the rural landscape over the past 30 years is the isolated, linear, reductionist approach to natural resource management, in which the management of forest, water and agriculture is approached sectorally. While agriculture forms the basis for the livelihoods of most rural people in Nepal, the people also rely on forests for food, fodder, fuel, grazing and non-timber products. This reliance applies particularly to economically marginalised, natural-resource-dependent people who cannot obtain all of their livelihood needs from their own land. A more recent phenomenon is the loss of connection between farm and forest, both vital elements of local food security and livelihoods. In addition, sectoral responses to climate change are not evident.

The introduction of agricultural monocultures pushed back the spirit of agroforestry in the last 20 years (Paudel 2012). An example is the introduction of a ‘populist community forestry approach’ with supportive policies and legislation (MOFSC 1993) instead of support for agroforestry practices.
These changes in rural socioeconomic and ecological dynamics, with shortages of labour and other vital inputs, bring opportunities to reintroduce the less-labour-intensive agroforestry approach. Agroforestry could also mitigate climate change threats and increase local food production to improve food security for the poor and marginalised by restoring abandoned farm lands to production.

**Keywords**

Feminisation of labour, out-migration, middle hills

**References**

FAO. 2010. ‘Climate smart’ agriculture: policies, practices and financing for food security, adaptation and mitigation. FAO, Rome.

IFAD. 2012. IFAD’s Adaptation for Smallholder Agriculture Program (ASAP). IFAD, Rome.


Change of forest cover and shifting cultivation in upland Thua Thien Hue province during 2000–2011: causes and implications for sustainable agricultural development

Ho Dac Thai Hoang*, Phan Thi Ngoc Ha², and Hoang Hao Tra My¹

¹Hue University of Agriculture and Forestry, 102 Phung Hung Street, Hue City, Vietnam
²Hue University of Science, 77 Nguyen Hue Street, Hue City, Vietnam

*Corresponding author: hodacthaihoang@huaf.edu.vn

Forest cover in Vietnam has changed dramatically in the last few decades for many reasons, chiefly slash-and-burn cultivation (Hoang and An 2007; Sunderlin and Huynh 2005). We measured the change of forest cover from 2000 to 2011, assessed the status of slash-and-burn cultivation and identified sites appropriate for sustainable food crop production, to support food security for and adaptation to climate change by the Pakôh ethnic minority in Hong Bac commune, Aluoi district, Thua Thien Hue province.

We analysed Landsat 7 and Spot 5 satellite images to identify changes in land use and forest cover. We also used GIS, in combination with indigenous knowledge, to identify sites most appropriate for sustainable food crop production that could achieve both food security and forest protection. We held interviews with key informants, group meetings with villagers and participatory field discussions in 4 villages of Hong Bac commune to learn about traditional slash-and-burn cultivation and the needs of the communities.

Forest cover has changed significantly during 2000 to 2011; a large area of rich forest was degraded to poor forest and bare land. Some 115 ha of rich forest and 63 ha of average forest were lost, while the area of poor forest increased by 163 ha. The area of acacia plantations was enlarged by 88 ha. Different causes of natural forest degradation were identified, principally slash-and-burn cultivation, followed by illegal logging and forest fire, among others. Generally, forest cover in Hong Bac has increased during the study period thanks to the national forest plantation program, under which bare land and fallow plots in shifting cultivation are afforested with Acacia. However, large areas of rich and average forests were felled to create slash-and-burn plots for food production. Thus, the forest cover increased, but the quality of natural forests decreased.

Slash-and-burn cultivation is closely associated with the livelihood of ethnic minorities in upland areas of the Truong Son mountain range, especially the Pakôh people. Ethnic minorities face problems caused by the lack of arable land. The area of slash-and-burn cultivation has been enlarged since 2000, mainly through the felling of rich and average natural forests on rich soils.
The areas of enriched fallow and bare land also increased. The area of slash-and-burn cultivation in Hong Bac commune increased from 204 ha in 2000 to 344 ha in 2005, to 372 ha in 2011. Almost all ethnic minorities practise slash-and-burn cultivation. That as practised in Pakôh community is closely associated with the tradition of honouring local spirits (Trần and Nguyễn 2003; Nguyễn et al. 2004; Hoàng 2007).

Almost all slash-and-burn plots are located in rich or average natural forests, close to water and along roads. Normally, the Hong Bac farmers fell all trees to grow upland rice in the first year. Because the hillsides are steep, rice is sown in holes. After the first year, the soil becomes degraded and eroded, and cassava and other food crops, including vegetables, are planted in the following 2 to 3 years. The land is then left fallow for another 3 or 4 years for the soil to recover its fertility. Although these slash-and-burn practices meet the needs of the local people, they cause deforestation, which in turn causes loss of biodiversity, soil erosion and reduced livelihoods.

In recent years, instead of leaving the soil fallow, the Pakôh people have planted Acacia and other forest trees. This increases the area of forest but reduces the area of land for food production. To overcome this problem, the farmers resort to illegal felling of natural forest. To help the farmers avoid the need to do this, we used local knowledge and GIS to identify land appropriate for sustainable crop production. We identified 456 ha as potential cultivable land. The land is currently under forest, but because it is appropriate for intensive cultivation, its deforestation would minimise environmental damage. The permanent allocation of this land to sustainable intensive food production will reduce problems of forest destruction caused by slash-and-burn cultivation.

Developing and promoting the adoption of improved sustainable cultivation techniques is of great importance to supporting the sustainable production of food on this land. Building the capacity of the local farmers in sustainable cultivation and food security strategies is also of vital importance.

Keywords
Hong Bac commune, Vietnam

References


Conservation agroforestry practices and the scaling-up potential in north-western Vietnam

Hoang Thi Lua*1, Ha Van Tiep2, Vu Duc Toan3, Nguyen Thi Hoa1, Elisabeth Simelton1, Nguyen Van Chung4, Phung Quoc Tuan Anh4

1 World Agroforestry Centre, ICRAF Vietnam, Hanoi, Vietnam
2 Forest Science Institute Vietnam, Son La, Vietnam
3 Tay Bac University, Son La, Vietnam
4 NOMAFSI, Son La, Vietnam

*Corresponding author: hlua@cgiar.org

This abstract presents results from a farming system diagnosis survey based on participatory diagnosis and assessment and on focus group discussions in 17 villages, and on in-depth interviews with 45 farmers regarding the farming systems in north-western Vietnam. The results will contribute to a better understanding of the kinds of farming practices that are being implemented in the region and which types of agroforestry systems have potential for wide-scale adoption. This information will also help improve curricula for extension training. Subsequent consultations with local policymakers will provide recommendations for support.

Agroforestry systems - combinations of trees and crops on farms - are established around the world to diversify and strengthen household incomes while enhancing soil fertility and reducing soil erosion (Young 1989). Increasingly, they are also receiving attention as climate-smart agriculture, serving climate adaptation and mitigation functions (Nair 2012; Matocha et al. 2012).

In Vietnam, agroforestry has long been recognised as a sustainable land-use model and is implemented in many regions (Nguyen et al. 2006), Garden–pond–cage (VAC) and forest–garden–pond–cage systems are examples of this approach. However, 30 years after VAC systems were introduced, the spread of VAC and other agroforestry systems in northern mountainous Vietnam remains limited. An investigation of the current farming systems, elucidating the reasons for the limited adoption of agroforestry practices in the region, would lay the groundwork for effective agroforestry research.

The overall objective of this study was to analyse the farming systems in the region and to figure out the limitations to sustainable land uses there. We asked 4 research questions:

(1) What farming systems are being practised in the north-west?
(2) What are the key strengths and weaknesses of these systems in terms of environmental impacts? In particular, what are the environmental and economic benefits?
(3) Which species (fodder shrubs and trees) could contribute to the mitigation of soil erosion in improved agroforestry systems in the region?

(4) What are the reasons for the low uptake of agroforestry practices in this region?

A participatory diagnosis and assessment was conducted in 17 villages in 11 communes in 6 districts. Mapping of agroecological zone transects was backed up by participatory appraisal exercises and village meetings. Along each transect, we recorded current and dominant land use systems at different elevations and slopes, including crop varieties, cropping systems (monocropping or crop association), and farming calendars in relation to biophysical indicators such as soil type, erosion status and resource availability.

Focus group discussions were held in each village to help us understand crop management, the economics of the dominant cropping systems and indigenous methods for preventing erosion.

Structured questionnaires were carried out with 45 farmers to cover more in-depth variations between households and regions. The results will be complemented with information from another questionnaire conducted with 300 farmers in the north-west in July 2012.

Preliminary results from the village meetings and the interviews showed that the predominant land use on sloping land (>15°) in the villages was the monocultivation of maize. These farming systems were characterised by low productivity due to high production costs (fertiliser, labour) and, notably, declining soil fertility as a result of significant soil erosion and intensive monocropping practices. Most of the farmers practising this farming system stated that its main drawback was decreasing crop yield and soil fertility. Nevertheless, few soil conservation measures are practised.

Further, most of the farmers had never heard the term ‘agroforestry’. One reason for the limited uptake of agroforestry could be that commune extension workers are typically specialised or experienced in only a few trees or crops, and few have training in combining those and other species into agroforestry systems. While many extension workers are familiar with the VAC concept, they don’t necessarily associate this as agroforestry or a type of conservation agriculture.

A very small number of farmers practised a few conservation measures, including pipelines to divert water, grass or pineapple strips along contours, and stone fences. There is an increasing demand for multipurpose species, such as fodder grass, which can be grown along contours for conservation purposes, as it requires no tillage, and for cover crops (e.g. Arachis pintoi) that can also be used as green mulch to improve soil fertility and reduce erosion (Argel et al. 2005).

After finalising the survey with 300 households we expect to provide a robust mapping of current land uses and a thorough analysis to complement the first set of surveys.
This study was carried out as part of the ‘Agroforestry for improving livelihoods in north-western Vietnam’ project of ICRAF Vietnam, Tay Bac University, the Northern Mountainous Agriculture and Forestry Science Institute, the Forest Science Institute Vietnam and the Department of Agriculture and Rural Development in Son La, Dien Bien and Yen Bai. The project is funded by ACIAR and ICRAF.

**Keywords**

Monoculture, farming system assessment, farmer adoption

**References**


Agrarian transition in the northern uplands of Lao PDR: a meta-analysis of changes in landscapes and livelihoods

Jean-Christophe Castella*1,2 Guillaume Lestrelin1,2 Pauline Buchheit3

1 Institut de Recherche pour le Développement, Vientiane, Lao PDR
2 Centre for International Forestry Research, Bogor, Indonesia
3 AgroParisTech, Paris, France

*Corresponding author : j.castella@ird.fr

Within a decade, entire upland regions of northern Lao PDR have shifted from a ‘forest–subsistence agriculture’ matrix to a landscape dominated by intensive commercial agriculture. This agrarian transition affects livelihoods in many different ways depending on local circumstances (Cramb et al. 2009). High diversity in local socioeconomic conditions and use of natural resources create a complex picture with nothing like a typical district, village or even household. This raises major methodological problems in generalising locally obtained empirical results and drawing lessons relevant to policy formulation at the regional level.

This study aimed at characterising the diversity of land-use change dynamics in the uplands of northern Lao PDR and understanding their driving forces and effects on livelihoods and forest resources. We conducted a meta-analysis of case studies to identify sites that evolved along the same trajectories of land use change. Our underlying assumption was that locations (villages, districts) following similar trajectories at a different pace or with a time lag can learn from each other and avoid repeating mistakes. If institutional structures and mechanisms are in place to support exchanges across scales and actors, this learning process can facilitate decision-making in times of uncertainty. Furthermore, the identification of locations that share the same opportunities and constraints for development may facilitate the design of appropriate technologies and spatially differentiated policies. Through an understanding of the local processes of land use change and their main driving forces, targeted introductions of technical and organisational innovations would have better chances to succeed and achieve a greater impact at the regional level.

From 2008 to 2010, we conducted 18 case studies across the northern mountains of Lao PDR. At each study site, we dedicated 6 months’ intensive field work to landscape and livelihood analysis through agro-ecological zoning using time series of land-use maps from remote sensing data, household surveys and participatory scenario exploration with local stakeholders. The results were combined with secondary data from 27 other case studies so as to cover a larger range of ecosystems and development situations (Fig. 1).
Secondary data were obtained mainly from student projects spanning 4 months to 2 years. In addition, 2005 national census data were used to document all case studies more systematically.

The meta-analysis described the local trajectories of land use and livelihood changes pertaining to each site with a limited set of indicators and then combined them into a comparative frame-work that allowed statistical comparison across sites. A series of 30 indicators of change in agriculture, livelihood and natural assets were selected to review and classify all case studies according to various modalities (Fig. 2). By using standardised ordinal variables to describe the case studies, the comparative framework could include a large range of case studies that had different scopes and methods and therefore generated heterogeneous datasets. Finally, statistical analyses were conducted to build a typology of case studies and to test the relative influence of different drivers of change.

**Figure 1:** Location of the case study sites in the northern uplands of Lao PDR.
Our results show a major transformation of agricultural systems away from shifting cultivation, with a rapid diversification of agricultural production and segregation of the agricultural and natural forested landscapes. As expected, physical accessibility of the study sites constitutes the single most important factor explaining local variations in land use and livelihoods (Fig. 3).

Population density, tenure rules and ethnic diversity also play important roles. Although many qualitative analyses have drawn similar conclusions, the meta-analysis outlines the intensity of these trends, their spatial distribution and their driving forces.

Three main development trajectories emerged: a mainstream trajectory which reflects market integration and a gradual diversification of land use and livelihood activities, and two alternative pathways which differentiate farm investment and land use intensification in the lowlands and in the uplands respectively.
The transition from subsistence to market-oriented agriculture results from the combined effect of internal and external, local and global forces of change. The main driving forces of land use change in the mountainous areas of Lao PDR are (1) the changing accessibility to market, education, health services and technical information; (2) the rapid expansion of commercial plantations in relation to market demand for rubber, biofuels, timber and animal feed; (3) successive land policies (e.g. land use planning, land allocation, village consolidation and resettlement, land concessions); and (4) environmental regulations aiming at preventing land degradation, deforestation and loss of biodiversity. The complex mechanisms of interaction between livelihood systems, market forces and public policies require thorough investigation at the interface between local and regional processes of change in order to mitigate their potential negative effects on poverty and on environmental degradation. Our meta-analysis of case studies addresses such research challenges. Further monitoring of the agrarian transition by adding further case studies will help provide adapted policy responses (i.e. timely and locality specific) to emerging changes.

We conclude that there is no need to ‘force’ the eradication of shifting cultivation. as the practice will disappear anyway in most accessible landscapes. Development effort and resources would be better invested in buffering the potentially negative consequences of rapid market integration on people (e.g. through education) and the environment (e.g. through soil and forest conservation). Improved education in remote rural areas could keep the next generations out of poverty while reducing their dependence on forests and natural resources. On the other hand, land degradation, biodiversity loss and subsequent decreases in land productivity are avoidable outcomes of agricultural intensification.

Figure 3: Patterns of livelihood change in northern Lao PDR from a principal component analysis.
It is possible to promote a smooth transition from shifting cultivation to conservation agriculture and avoid the ‘resource curse’ of conventional agriculture (i.e. with tillage, chemical fertilisers and pesticides). Yet conservation agriculture practices as they have been promoted in recent years are only at the beginning of their adoption phase; strong commitment and political will are required to consolidate promising results and achieve wide-ranging and lasting impacts.

**Keywords**

Land use change, Laos, subsistence agriculture

**Bibliography**


*Corresponding author: florent.tivet@cirad.fr

Xayabury province, in southern Laos, has long been a crossroads between Laos and Thailand, and became the trading hub between these two countries with the opening of the international border in 2006. Following the introduction of new economic mechanisms in 1986, promoting trade, cash crops underwent a considerable boom and took a predominant role in the farming systems of the region (Lestrelin et al. 2012). A semi-intensive Thai agriculture, characterised by intensive ploughing (even on steep slopes of up to 40%) and the use of inputs (e.g. hybrid seeds of maize, pesticides and mineral fertilisers), was gradually imposed in the region. As a consequence, the associated short-term fallow period, systematic removal of crop residues (by cattle grazing and fire) and repeated mechanical operations rapidly weakened the rainfed ecosystem, leading to marked soil degradation.

We estimated the evolution of the forest, fallow and cultivated areas from 1982 to 2010, and the depletion of the soil organic carbon (SOC) stocks between native vegetation (NV) and cultivated fields managed under conventional tillage (IT).

We analysed Landsat satellite imagery from 1982, 1989, 2000, 2005 and 2010 to assess the land-use changes and their effects on SOC dynamics in the southern part of Xayabury province (~3050 km²; 17°28’37’’–18°14’05’’N, 100°56’12’’–101°24’29’’E). All images were orthorectified to a geographic projection (UTM zone 47 N, WGS-84). The 10 spectral profiles were aggregated into 3 classes (forest, crop, fallow). An unsupervised classification of these images, based on the Normalised Difference Vegetation Index (Huete et al. 2002), was conducted to improve the accuracy of the classification.
Only 1 group was built, regrouping all rainfed crops. In addition, a field survey was conducted in June to July 2011 to validate the classification. Five locations representing the main morphopedological units were selected for soil sampling. Soil samples were collected in June and July 2009 in NV and IT fields. In each land use, 3 replicates were collected at 3 depths (0–10, 10–20 and 20–30 cm). Bulk samples were oven-dried at 40 °C, gently ground and sieved through a 2-mm sieve. Subsamples of bulked soil were finely ground (<150 mm) for measuring SOC concentration by the dry combustion method with an elemental CN analyser (TruSpec CN, LECO, St Joseph, MI, USA).

The overall forest area decreased by 52% (Table 1), from 194 780 ha in 1982 to 93 801 ha in 2010 (Fig. 1).

Table 1. Estimates of forest, fallow and cultivated areas (ha) from 1982 to 2010 from Landsat satellite imagery of southern Xayabury province, Laos.

<table>
<thead>
<tr>
<th>Land use</th>
<th>Area (ha)</th>
<th>1982</th>
<th>1989</th>
<th>2000</th>
<th>2005</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crops</td>
<td></td>
<td>77 486</td>
<td>77 486</td>
<td>129 806</td>
<td>148 099</td>
<td>139 130</td>
</tr>
<tr>
<td>Fallow</td>
<td></td>
<td>28 620</td>
<td>25 044</td>
<td>86 966</td>
<td>71 420</td>
<td>72 127</td>
</tr>
<tr>
<td>Forest</td>
<td></td>
<td>194 780</td>
<td>170 040</td>
<td>88 290</td>
<td>85 543</td>
<td>93 801</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>300 886</td>
<td>284 224</td>
<td>305 062</td>
<td>305 062</td>
<td>305 058</td>
</tr>
</tbody>
</table>

Figure 1. Permanent area under cultivation from 1982 to 2010 (56 398 ha, 19% of the region) and land use distribution in 2010 (dark green, forest; light green, fallow; yellow, fields).

By contrast, the area under cultivation increased by 80%, to 139 130 ha. In addition, the crop plus fallow areas doubled. The fallow area increased from 37% of the cultivated area in 1982 to 52%.
Intensive cultivation has been practised in the uplands of the region for several decades, mainly for the production of cotton and maize cash crops. Crops of rice bean, sesame, groundnut and Job’s tears are also grown. In contrast with the mountainous regions of Laos, a large proportion of fields are cultivated every year (Fig. 1a), and only short-term fallow is used, owing to the high soil fertility (igneous and clayey schist parent materials) and high commodity prices between 2000 and 2010. Thus, much of the land left fallow between 2000 and 2010 was rested only briefly, resulting in land degradation, soil erosion and loss of profitability.

SOC concentrations were higher in soils derived from igneous parent materials (Table 2).

Table 2. SOC concentrations (g kg⁻¹) and mean clay content (0–30 cm) under native vegetation (NV) and in cropped fields managed under conventional tillage (CT) in southern Xayabury province, Laos.

<table>
<thead>
<tr>
<th>Village</th>
<th>Land use</th>
<th>Parent material</th>
<th>Clay content (g kg⁻¹)</th>
<th>SOC (g kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>0-10 cm</td>
<td>10-20 cm</td>
</tr>
<tr>
<td>Nongpakbong</td>
<td>NV</td>
<td>Unfolded sandstone and claystone</td>
<td>400</td>
<td>26.80</td>
</tr>
<tr>
<td></td>
<td>CT1</td>
<td></td>
<td>335</td>
<td>13.76</td>
</tr>
<tr>
<td></td>
<td>CT2</td>
<td></td>
<td>427</td>
<td>13.46</td>
</tr>
<tr>
<td></td>
<td>CT3</td>
<td></td>
<td>306</td>
<td>9.72</td>
</tr>
<tr>
<td>Houayphet</td>
<td>NV</td>
<td>Clayey schale (kaolinite)</td>
<td>502</td>
<td>33.84</td>
</tr>
<tr>
<td></td>
<td>CT1</td>
<td></td>
<td>482</td>
<td>21.34</td>
</tr>
<tr>
<td></td>
<td>CT2</td>
<td></td>
<td>452</td>
<td>15.07</td>
</tr>
<tr>
<td>Paktom</td>
<td>NV</td>
<td>Clayey schale (illite) + igneous rocks</td>
<td>421</td>
<td>31.09</td>
</tr>
<tr>
<td></td>
<td>CT1</td>
<td></td>
<td>339</td>
<td>23.68</td>
</tr>
<tr>
<td></td>
<td>CT2</td>
<td></td>
<td>403</td>
<td>23.19</td>
</tr>
<tr>
<td></td>
<td>CT3</td>
<td></td>
<td>473</td>
<td>18.53</td>
</tr>
<tr>
<td>Nahin</td>
<td>NV</td>
<td>Basic igneous rocks</td>
<td>509</td>
<td>46.50</td>
</tr>
<tr>
<td></td>
<td>NV</td>
<td></td>
<td>446</td>
<td>30.27</td>
</tr>
<tr>
<td></td>
<td>CT1</td>
<td></td>
<td>473</td>
<td>18.66</td>
</tr>
<tr>
<td></td>
<td>CT2</td>
<td></td>
<td>500</td>
<td>20.59</td>
</tr>
<tr>
<td></td>
<td>CT3</td>
<td></td>
<td>493</td>
<td>19.95</td>
</tr>
<tr>
<td></td>
<td>CT4</td>
<td></td>
<td>467</td>
<td>15.85</td>
</tr>
<tr>
<td>Houaybouha</td>
<td>NV</td>
<td>Basic igneous rocks (gabbro, dolerite)</td>
<td>358</td>
<td>48.93</td>
</tr>
<tr>
<td></td>
<td>CT1</td>
<td></td>
<td>437</td>
<td>22.73</td>
</tr>
<tr>
<td></td>
<td>CT2</td>
<td></td>
<td>487</td>
<td>24.06</td>
</tr>
<tr>
<td>Bouamlao</td>
<td>NV</td>
<td>Basic igneous rocks (gabbro, dolerite)</td>
<td>412</td>
<td>30.42</td>
</tr>
<tr>
<td></td>
<td>CT1</td>
<td></td>
<td>390</td>
<td>23.66</td>
</tr>
<tr>
<td></td>
<td>CT2</td>
<td></td>
<td>403</td>
<td>28.79</td>
</tr>
<tr>
<td></td>
<td>CT3</td>
<td></td>
<td>456</td>
<td>22.27</td>
</tr>
</tbody>
</table>
They were highly stratified with depth under NV, but were uniform in the 0–20-cm layer under CT owing to mixing by ploughing (Sá and Lal 2009). Conversion from forest to cultivated land has resulted in a severe loss of SOC in all situations. SOC was significantly lower in cropped fields than under NV at 0–10 cm.

The average concentrations in the igneous-derived soils (in Nahin, Houaybouha and Bouamlao) decreased from 39.0 g kg\(^{-1}\) under NV to 21.3 kg kg\(^{-1}\) under CT, a decline of ~44%. The concentrations in the sandstone-derived soils (in Nongpakbong) decreased from 26.8 to 12.3 g C kg\(^{-1}\), a decline of ~54%. The concentrations in the clayey shale-derived soils decreased by 30% in Paktom and by 46% in Houayphet. The primary driving forces for the decline of SOC under CT are the disruption of soil aggregates; marked changes in the soil environment (temperature, moisture and oxygen), which affect microbial activity; and the attendant greater access of SOC to microbial processes. In addition to accelerated soil erosion (Lal 1976), the bare soil surface under CT is exposed to frequent wet–dry cycles, enhancing the turnover of aggregates (Beare et al. 1994).

The region benefits from exceptional soil fertility and market access. However, satellite imagery highlights drastic land use changes during the last 3 decades and a massive depletion of SOC. The SOC concentration is reduced by the conversion of native vegetation to arable land managed under plough-based tillage, leading to a depletion of 30% to 54% of the original SOC content. This means that even in this region, the natural environment can be degraded very rapidly, with negative economic and social consequences.

**Keywords**

Soil fertility, natural resource management, plough-based tillage, maize

**References**


Long-term erosion measurements on sloping lands in northern Vietnam: impact of land use change on bed load output

Didier Orange*2, Pham Dinh Rinh*1, Tran Duc Toan*1, Thierry Henri des Tureaux2, Mathieu Laissus2, Nguyen Duy Phuong1, Do Duy Phai1, Nguyen Van Thiet1, Nicolas Nieullet2, Sebastien Ballesteros2, Brice Lequeux2, Phan Ha Hai An2, Yannick Lamezec2, Chloë Mitard2, Marion Mahé2, Romain Bernard2, Henry Ducos2, Delphine Zemp2, Jean-Louis Janeau2, Pascal Jouquet2, Pascal Podwojewski2, Christian Valentin2

1 Soils and Fertilizers Research Institute, VAAS, MARD, Hanoi, Vietnam
2 IRD, UMR211-BIOEMCO, University of Paris 6, France; posted at SFRI, Hanoi, Vietnam

*Corresponding authors:
pvrinh.tb@gmail.com, didier.orange@ird.fr, toantransfri@gmail.com

Soil erosion in highly incised catchments of northern Vietnam harms both upstream and downstream communities (Valentin et al. 2008). Sediment discharged from these catchments reflects a loss of fertile topsoil that farmers depend on for the production of crops and pastures. In addition, increased sediment loads in streams and rivers reduce water quality and the longevity of water storages, with significant economic implications.

The aim of this study was to improve the knowledge of erosion processes on cultivated steep slopes and of sediment transport by river at the small catchment scale (<1 km²) and in relationship to the land-use management of steep agricultural catchments. We set up a long-term project to monitor the hydrology and erosion in a catchment with 1 main outlet (MW) and 4 sub-catchments (W1–W4; Fig. 1). The entire 50-ha catchment has slopes between 40 and 100% leading to no easy solutions for mechanization.

The 5 monitoring weirs were equipped in 2000 with concrete sediment traps, water-level recorders and automatic water samplers to measure and assess discharge and sediment loads (Tran Duc Toan et al. 2003). This catchment is included in the research network of MSEC (Multiscale Environmental Changes; Valentin et al. 2008).

The catchment lies within Dong Cao village, 60 km north-east of Hanoi, and is typical of the agricultural environment of the agrarian transition occurring in northern Vietnam from the late 1980s. Over the past 30 years, farming on the hillslopes has moved from intensive upland rice to cassava to a mix of cassava, pasture, fodder and planted forest. The predominant land use has gradually changed from cassava to tree plantations and long fallows, with a decline in the total area of cassava from 40% of the catchment area in 2001 to less than 0.5% in 2004. The reasons for these land use changes are complex (Clément et al. 2007).
Figure 1. Plan of the Dong Cao catchment, northern Vietnam (MSEC network).

Figure 2. Annual cumulative bed load (lines) measured in Dong Cao catchment, northern Vietnam. Columns show monthly rainfall. Weir 1, forested; weir 2, pasture fallow (*Bracharia ruziensis*) from 2003; weir 3, cassava; weir 4, old natural fallow (>10 years).
Sub-catchment W1 was planted in 2001 to mainly *Acacia mangium* forest with a few *Venititia montana*. The trees were cut in 2006 and replaced by natural fallow. Sub-catchment W3 was planted to cassava until 2003 and has been left fallow since 2004. The entire catchment has been left fallow since 2006. The decline in cassava cropping brought the opportunity in 2003 to introduce a livestock component with the sowing of *Brachiaria ruziziensis* for fodder on sub-catchment W2 (from 2003 to 2005). Sub-catchment W4 is covered in natural long-term fallow with dense shrubs.

The annual soil loss recorded through bed load measurements decreased from 3.6 Mg ha\(^{-1}\) y\(^{-1}\) in 2001, before the establishment of pasture or plantation, to 0.1-0.3 Mg ha\(^{-1}\) y\(^{-1}\) from 2004.

Bed load monitoring from 2000 to 2005 highlights the rapid impact of land use change on soil loss (Fig. 2).

At W1, our results highlight the decline in bed load due to the shift from cassava to plantation forest in 2001. Before 2001, W1 lost a high bed load (9 Mg ha\(^{-1}\) y\(^{-1}\)). Only 1 year after the forest was planted, the bed load decreased to only 2 Mg ha\(^{-1}\) y\(^{-1}\), and in subsequent years it declined to nil, suggesting that runoff contributing to sediment discharge had ceased.

At W2, measurements clearly show a decrease in soil loss within the first year after the shift from cassava to improved fallow in 2003. The initial establishment of the grass, with the associated bare soil, caused an initial increase in erosion (to 3 Mg ha\(^{-1}\) y\(^{-1}\)). Soil losses subsequently declined to <0.2 Mg ha\(^{-1}\) y\(^{-1}\).

W3 (cassava then natural fallow from 2004) consistently recorded the highest bed loads. In 2001, the bed load discharge reached almost 12 Mg ha\(^{-1}\) y\(^{-1}\); this was reduced to ~1 Mg ha\(^{-1}\) y\(^{-1}\) from 2004, since the cassava plantation ended. The decrease in 2002 was due solely to a reduction in rainfall (1047 mm vs. 10-year average of 1500 mm).

At W4 (old fallow), there has been no land-use change. High rainfall in 2001 caused a high bed load, but in other years the bed load was <0.5 Mg ha\(^{-1}\) y\(^{-1}\).

Long-term continuous monitoring of erosion in Dong Cao catchment shows that the bed load recorded at catchment level is better explained by land use change than by land clearing. Indeed, even if forests and fodder crops effectively eliminate erosion 1 year after establishment, their establishment induces the highest erosion load. A future study will report on changes in suspended load.

**Keywords**

Soil erosion, surface runoff, dead mulch cover, maize cropping
References


Farmers’ perception of soil erosion as a risk to their livelihood – scenario analysis with farmers in the northern mountainous region of Vietnam

Oleg Nicetic¹, Amanda Lugg², Pham Thi Sen³, Le Thi Hang Nga¹, Le Huu Huan³, Elske van de Fliert¹

¹ Centre for Communication and Social Change, School for Journalism and Communication, University of Queensland, Brisbane, Queensland 4072, Australia
² Australian Volunteers for International Development, Ha Noi, Vietnam
³ Northern Mountainous Agriculture and Forestry Science Institute, Phu Tho, Vietnam

Corresponding author: o.nicetic@uq.edu.au

Soil erosion is a major factor limiting sustainable maize production in the northern mountainous region of Vietnam. Erosion problems are complex owing to a combination of socioeconomic factors (including increased population pressure, land scarcity and market development) and common agricultural practices (including burning of organic residues, ploughing on slopes and free grazing) (Valentin et al. 2008). Vietnamese scientists, supported through a range of internationally funded research projects, have addressed erosion problems on sloping lands for many years, and various technologies have been developed, including mulch-based direct sowing, mini-terraces, intercropping with legumes, and diversification and rotation of crops (Le et al. 2003, Ha et al. 2003, Le and Ha 2008). Unfortunately, even though these erosion prevention methods did appear to be effective at the research sites, scaling up of production systems that use these methods has been slow and challenging (Le et al. 2003). This abstract outlines a preliminary social inquiry undertaken in 2011 and 2012 as a component of an ACIAR-funded project that investigated farmers’ perceptions of soil erosion as a risk to their livelihood in an attempt to explain the slow adoption of erosion management practices.

The inquiry was influenced by the work of Schoell and Binder (2009), who developed a structured mental-models approach to investigate farmers’ perceptions of risk. In this model, farmers’ perceptions are elicited in the context of their livelihood. The perceptions are then compared with the scientists’ perceptions about farmers’ attitudes towards erosion. Our inquiry was based on a scenario analysis, which involved three steps.

The first step was a workshop with Vietnamese scientists involved in research on sustainable management of sloping lands in Lai Chau and Son La provinces. The aim of the workshop was to identify the scientists’ perception of farmers’ understanding and attitudes towards soil erosion.
The second step was for Vietnamese scientists to develop scenarios of potential risks of soil erosion that would then be used to facilitate discussions with farmers. Three scenarios were developed.

The first scenario described a positive outcome for farmers. With the help of local government and extension services, farmers would change their practices to a sustainable soil management system that reduces erosion and brings long-term benefits, despite the initial increase in labour input. In the second scenario, farmers are not managing their land appropriately and sell their land to an international company to compensate for declining productivity. The company invests in sustainable soil management and, as a result, increases productivity. After farmers realise that the land production capacity is much higher than first thought they want to buy it back. However, that is not possible, as the company is not willing to sell the land back, and the farmers have spent the money they received for the land. Finally farmers have to move from their village in search of work elsewhere. The third scenario describes the disastrous long-term consequences of soil erosion if farmers did not change their practices. The fertility of their land and, consequently, their income declines to the level where farmers can no longer afford to pay the school fees for their children and they hardly have enough food to eat. In desperation, the farmers either break the law and cut the forest to claim more land but then have to face the legal consequences, or leave their village to look for work.

The third step involved discussion sessions with farmers around the three scenarios. In each commune, these discussion sessions were held with two groups of farmers separately, one that was directly involved in the ACIAR project activities, the other with no prior involvement. The sessions were conducted in Lai Chau province with farmers in Ban Bo and Giang Ma communes, and in Son La province in Na Ot and Phueng Luong communes. Open-ended questions were asked to probe for the farmers’ opinions about the scenarios.

Scenario analysis revealed that farmers are aware of soil erosion. In three of the four communities, the farmers see erosion as a problem for the next generation, but they believe that for the time being they can compensate for the loss of soil by increasing fertiliser use. The lack of mulching material and additional labour required to practise erosion management methods are perceived as the main barriers to the implementation of sustainable soil management. Farmers not directly involved in the project have a stronger sense of loyalty to traditions than farmer researchers participating in the trials, and see the change of cultivation practices as hanging to their ‘culture’. Farmer researchers, moreover, see the change of practices more as a risk than an opportunity, but they are more open to change if they can see clear short-term benefits of the change, such as reduced labour input with minimum tillage.

It is interesting that all of the farmer groups engaged in the sessions could outline contingency plans if erosion reduced the fertility of the land to the level where they could not grow maize anymore.
These contingency plans include the management of different cropping systems such as agroforestry, selling eroded land and buying new land, cutting forests and moving to new areas. Although most communities have communal regulations on the use of water, land and forest, decisions on how to farm and how to mitigate soil fertility problems are made at the household rather than the community level, and hence through the action of individuals, not through collective action.

All groups agreed that the scenarios presented were realistic, indicating that Vietnamese scientists had a good understanding of the farmers’ perceptions of erosion. However, the notion of the scientists and extension officers that farmers do not care about erosion is an oversimplification. Farmers are aware of both the problem of erosion and to some extent the methods of mitigation, but they have other priorities and shorter-term goals that need to be addressed to maintain current production and cash flow. For them, erosion, with all its associated problems, is a longer-term risk that the next generation will have to deal with. In this context, to be adopted by farmers, any erosion management strategy will have to have some short-term benefits in order to be accepted by farmers.

**Keywords**

Farmer perceptions, risk management

**References**


Portfolio 1. From conventional agriculture to today’s

1. Rice, a food staple and the cornerstone of agricultural production

In Southeast Asia, rice is a food staple and the cornerstone of agricultural production (101). Wherever the topography and water resources allow such landscaping, rice is cultivated in irrigated fields designed to retain and accumulate water (102).

The traditional cropping system is based on puddling, transplanting and ensuring a continuous water supply. It consumes a considerable amount of water and is labour-intensive. The maintenance of irrigated polders results in financial costs and social constraints that limit their extension (103).

2. Slash and burn, a traditional and ancestral way of agricultural production on non-irrigated land

As in many other countries in the South, agriculture in Southeast Asia is mainly undertaken by small-scale farming families whose priority goal is to feed the family. Wherever the topography and access to land or water do not enable food self-sufficiency, rice is grown with other cereals outside the landscaped areas. Slash and burn cultivation is the traditional way of managing natural resources. First, the forest is cleared and burnt to grow rainfed crops, i.e. relying exclusively on rainfall to water the crops (104).

Once forest has been converted into an agricultural field, soil preparation is repeated each year by cutting and burning weeds. This partially restores nutrients to the crops (105).

3. Rainfed agriculture and its constraints

Farmers practising rainfed agriculture face various difficulties, the main ones being a continuous decrease in soil fertility and increasing weed pressure over the years (106).

In the past, whenever the constraints facing agriculture became too great, fields were left fallow for several years, thus allowing soil fertility to be naturally restored over time. New fields were therefore cleared and cultivated to maintain the level of family production.

Shifting cultivation, with long-term fallow restoring soil fertility, has gradually become incompatible with the saturation of rural areas. However, conversion of natural forests into agricultural fields still occurs in the agriculture-forest boundary areas of Cambodia and Laos.

Small farmers constrained by limited access to land who cannot practise fallow any longer have no other alternative but to increase their use of inputs: inorganic fertilizers and chemicals to compensate for the rapid decrease in soil fertility.
101a – Vietnam.
Women coming back from the rice fields

101c – Vietnam
Hmong women harvesting rice

101b – Vietnam.
Manual rice threshing in the field

101d – Vietnam
A Hmong farmer harvesting rice

101a – Vietnam
Women coming back from the rice fields

J.-C. Maillard, Hoang Su Phi, 06/2003

101c – Vietnam
Hmong women harvesting rice

J.-C. Maillard, Hoang Su Phi, 06/2003

101d – Vietnam
A Hmong farmer harvesting rice

J.-C. Maillard, Hoang Su Phi, 06/2003

102a – Vietnam
Irrigated rice plain with slopes bared for maize cultivation in the background

102b – Vietnam
Irrigated rice terraces

102c – Vietnam
Harvest of irrigated rice

102a – Vietnam
Irrigated rice plain with slopes bared for maize cultivation in the background

D. Hauswirth, Moc Chau, 04/2010

102b – Vietnam
Irrigated rice terraces

102c – Vietnam
Harvest of irrigated rice

D. Hauswirth, Van Chan - Yen Bai, 06/2009

G. Da, Dien Bien Phu, 09/2003
102d – Vietnam
Braided irrigated polder

P. Grard, Van chan – Yen Bai, 06/2009

102e – Vietnam
Irrigated rice terraces

D. Hauswirth, Van Chan - Yen Bai, 06/2009

103a – Vietnam
Transplanting rice on irrigated rice terraces

D. Hauswirth, Van Chan - Yen Bai, 06/2009

103b – Vietnam
Transplanting rice on irrigated rice terraces

D. Hauswirth, Van Chan - Yen Bai, 06/2009

103c – Vietnam
Transplanting rice on irrigated rice terraces

D. Hauswirth, Van Chan - Yen Bai, 06/2009

103d – Laos
Preparing for rice transplanting in a paddy field

P. Lienhard, Laos, 01/2007
104a – Vietnam
Slash and burn cultivation

104b – Vietnam
Slash and burn cultivation

104c – Laos
Slash and burn cultivation

104d – Cambodia
Burning forest on poor sandy soils

105a – Vietnam
Burning a sloping field

105b – Vietnam
Smouldering
105c – Vietnam
Straw collected to carry out localized burning

D. Hauswirth, Moc Chau, 08/2011

105d – Vietnam
Burning a sloping field after harvest

T. Xuan Hoang, Moc Chau, 08/2011

105e – Vietnam
Field’s appearance after superficial burning

T. Xuan Hoang, Moc Chau, 08/2011

106a – Vietnam
Manual weeding of a rocky maize field in mountains

J.-C. Maillard, Dong Van, 04/2005

106b – Vietnam
Manual weeding by a Tay household

J.C. Maillard Dong Van, 2003

106c – Laos
Manual weeding of a rainfed maize plot

P. Lienhard, Laos, 05/2008

106d, 106e, 106f – Vietnam
Manual weeding of a rocky field

J.-C. Maillard, Dong Van, 2005

J.-C. Maillard, Dong Van – Ha Giang 04/2005

J.-C. Maillard, Dong Van, 2005

Conservation Agriculture and Sustainable Upland Livelihoods
Portfolio 2. Conventional agriculture

1. Intensification of agricultural production and market integration

In response to increasing market demand, agriculture has recently undergone rapid intensification in the most accessible areas. The area occupied by estate plantations (tea, coffee, rubber) targeting export markets or processing into biofuels (jatropha) has increased considerably (201). The production of cash crops for livestock feed (maize, cassava) has also increased spectacularly in numerous countries. (202). Development of contract-farming (agribusiness providing hybrid seeds, chemicals and short-term credit in return for a commitment to deliver production to a factory) and market integration have resulted in better access to inputs and a secured commercial outlet for farmers. It has also increased their dependence on agribusiness companies. (203)
201a – Vietnam
Extension of tea plantations on sloping land

P. Grard, Van chan – Yen Bai, 06/2009

201b – Vietnam
Extension of tea plantations on sloping land

P. Grard, Van chan – Yen Bai, 06/2009

201c – Vietnam
Tea cuttings some days before planting

P. Grard, Phu Tho, 06/2009

201d – Vietnam
Extension of tea plantations on sloping land

D. Hauswirth, Moc Chau, 04/2010

202a – Vietnam
Maize monocropping on sloping lands

D. Hauswirth – Son La, 10/2010

202b - Laos
Extension of areas under maize monocrops (spring)

H. Tran Quoc, Xayaburi, 04/2007

202c - Laos
Extension of areas under maize monocrops (summer)

P. Grard / Ken Thao, Xayaburi, 07/2005
203a – Vietnam
Frontage of a shop selling hybrid maize seeds

D. Hauswirth, To Mua (Moc Chau), 04/2010

203b – Vietnam
Sowing

D. Hauswirth, Moc Chau, 04/2010

203c – Laos
Herbicide treatment on bare soil using a back-pack sprayer

H. Tran Quoc, Xayaburi, 05/2008

203d – Vietnam
Farmer fertilizing a maize field on steep slopes

R. Kong, Moc Chau, 06/2010

203e – Laos
Loading and collection of harvested cobs by a maize trader

P. Lienhard, Xayaburi, 05/2008

203f – Vietnam
Factory processing maize into livestock feed

D. Hauswirth, Hoa Binh, 07/2010
2. Farming of increasingly fragile areas where ploughing has become generalized

Due to the rising saturation of rural land, increased agricultural production was first achieved by extending cultivation to the remaining available areas, such as sloping land in mountainous areas. Manual tillage or animal or motorized ploughing has become simultaneously generalized in increasingly fragile areas that were formerly preserved (204).

204a – Vietnam
Animal ploughing

D. Hauswirth, Moc Chau, 04/2010

204b – Vietnam
Animal ploughing

H. Tran Quoc, Xayaburi, 04/2008

204c – Vietnam
Animal ploughing

J.C. Maillard, Ha Giang, 04/2005

204d – Vietnam
Manual soil tillage

D. Hauswirth, Moc Chau, 04/2005

204e – Laos
Motorized ploughing

P. Lienhard, Kham, 11/2006

204f – Laos
Motorized ploughing

J.C. Maillard, Meo Vac - Ha Giang, 03/2007

204g – Laos
Ploughing on slopes

H. Tran Quoc, Xayaburi, 04/2008

204 – Laos
Motorized ploughing

J.C. Maillard, Ha Giang, 04/2005
3. Impact of intensification on a critical natural capital: soils

By limiting the quantity of weeds at the beginning of the agricultural season, ploughing helps to decrease subsequent labour requirements for weeding. However, this beneficial effect is limited to the first years after conversion into agricultural fields. Rapidly, ploughing no longer ensures weed control, thus encouraging supplementary use of herbicides. In hilly and mountainous areas, slopes are ploughed every spring for the sowing of annual rainfed crops. Once bare, the soils are no longer protected against erosion (205).

With the first rains, which can be intense under tropical conditions, soil is washed away by water runoff. Ploughed soils are very susceptible to erosion. Depending on biophysical conditions (slope length, soil cover, intensity of the first rains, soil type, etc.), it is estimated that from 10 to 100 t/ha of soil are lost by erosion every year under maize monocropping in mountainous areas of Laos and North Vietnam. Wherever the soil depth is limited to a few dozen centimeters, it is urgent to adopt alternative agricultural practices: erosion causes a rapid decrease in soil fertility. Some fields can already no longer be cultivated or restored. (206)
Conservation Agriculture and Sustainable Upland Livelihoods

206d – Madagascar
Erosion known as “Lavaka” in the highlands region
A. Chabanne, Madagascar, 1998

206e – Vietnam
Water erosion in a sloping field
D. Hauswirth, Moc Chau, 06/2010

206f – Laos
Soil washed away by runoff
A. Chabanne, Xayaburi, 06/2006

206i – Vietnam
Signs of water erosion in a sloping field
D. Hauswirth, Moc Chau, 04/2010

206j – Vietnam
Signs of erosion in a field ploughed
D. Hauswirth, Moc Chau, 04/2010

206g – Vietnam
Rainfed rice in an erosion slide
P. Grard, Van Chan – Yen Bai, 06/2009

206h – Vietnam
Appearance of a mountain soil after continuous erosion
D. Hauswirth, Moc Chau, 04/2010
Soil ends up in the rivers located in the valleys (207).

Paddy fields located downstream are damaged. Infrastructures (bridges, roads, dams) also suffer the consequences of erosion: landslides, silting. This destruction results in significant costs for society (208).
4. Is agricultural intensification with a low environmental impact at all possible?

Since the Second World War, the increase in food demand has led to the development of a conventional agriculture characterized by widespread ploughing and use of chemical inputs. Driven by the need for higher agricultural production, development of this agricultural model generates greater environmental impacts, raising a certain number of risks for the whole of society.

Inorganic fertilizers used with high-yielding hybrid varieties are being applied at ever increasing rates to compensate for losses in soil fertility. The extent of erosion and runoff cancels out part of the benefits expected from using such varieties: a significant share of the nutrients applied is leached, adding an environmental risk to the loss of agronomic and economic efficiency.

Expensive pesticides (herbicides, insecticides) are often used without sufficient knowledge of the application rules: treatments carried out without appropriate protective gear, use of excessively high doses, sprayers and tools cleaned in rivers. At the same time, the lack of facilities for recycling waste products leads to many packages containing chemical residues being left lying on the ground.

Rather than being based on the actual pest risk (threshold-based treatment), repeated chemical treatments have become systematized on various crops (insecticides sprayed every fortnight in tea plantations irrespective of pest status). This generates economic costs, soil and water pollution and reduces the sanitary status, hence the commercial value, of agricultural products. These recent practices do not only threaten farmers’ health: chemical molecules are dispersed into the air, soil, water and food, resulting in a major health risk. (209)
The high yields initially obtained through massive use of chemicals hid the severity of the environmental impacts associated with and facilitated by the continuation of unsustainable cultivated ecosystems: high susceptibility to biophysical and biological risks, loss of biodiversity, low resilience reflected in increased agricultural risks and limited economic efficiency.

Conventional agriculture ultimately proves to be incapable of developing certain under-exploited areas that nonetheless have proven agricultural potential, like the Plain of Jars in Laos.

Is this agricultural development model unavoidable?

What solutions can be proposed to meet growing food demand while protecting the environment?
Chapter 2
Design of Agricultural Systems

Subtopic 1
Overall approaches and transdisciplinary design

Vietnam
Communication in the mountains

D. Hauswirth, Moc Chau, 04/2010
Keynote 2: Understanding and using socioeconomic data on ethnic farmers to prepare for implementation and scaling up of CA projects

Christian Culas*1

1CNRS – EHESS, Centre Norbert Elias, Marseille, France

*Corresponding author: christianculas@yahoo.fr

Our objective was to analyze limitations of information on the sociocultural and economic situation of ethnic groups in the mountains of Vietnam to better implement CA programs in Vietnam.

CA implementation in a difficult or hostile environment

Conservation agriculture (CA) remains a controversial agricultural innovation, and its practical application is highly dependent on the understanding and direct motivation of farmers.

For example, the keynote to Chapter 6 of this conference says: ‘The first is that CA concepts and principles are counterintuitive and contradict the common tillage-based farming experience.’ We can add that the objectives of CA are also opposed, at least in part, to the dominant view of the Vietnamese authorities that agriculture must advance through equipment and chemicals. Both tools are symbols of an idealized modernity, as expressed in major state projects designed to transform lives and behaviours in rural areas, such as ‘Nông Thôn Mới’ (‘Building a new countryside’1). In Vietnam, most attempts at integrated farming, agroforestry and permaculture are tolerated but are considered marginal and confidential activities, without high economic potential. Under these conditions, CA projects should pay better attention to human and social components.

My presentation is not intended to stay on the marked paths of political correctness. As I show below, it is through an empirical and critical approach to ethnic populations’ local realities that we can find an anthropological key to the design and implementation of CA projects.

Communication between agrarian specialists and anthropologists

If the first element to facilitate the application of CA at the local level depends on knowledge of the farmers’ local reality, the second necessarily depends on exchange and communication between agrarian specialists and anthropologists.

My feeling is that many specialists in agriculture and technology look to new tools, methods and maybe social sciences because they understand that even the best technical approach is not efficient for introducing the ‘new’ concept of CA without a global understanding of the sociocultural–economic context. More or less clearly, agrarian specialists express the importance of the human factor in agricultural development projects. Studying and analysing these human factors is one of the responsibilities of social science.

But social science and exchanges between interdisciplinary specialists face important constraints:

• **Few social science research projects** in ethnic mountain areas in Vietnam focus on socio-agricultural dynamics and changes. For example, at this conference, a few authors are geographers, socio-economists, journalists and experts in communication, but some disciplines, such as sociology and anthropology, are not represented here.

• **Few projects take a multi-disciplinary approach from the project design stage.** Usually, development projects seek social science support when they start to encounter problems. In these cases, social science is the ‘fire brigade’ of the project. But by this stage, social scientists can save only part of the project, and usually it is too late to give substantive help.

• **Communication and exchange** between social science specialists and agricultural specialists is often weak or problematic and always limited in time.

• From the point of view of agricultural specialists, **social science literature is not easily readable**, and when they can understand it, they complain that it has **no practical application** in the project. From the social science point of view, development officers frequently request ‘recipes’ for ‘how to work with this social reality’, while the social science approaches try only to explain keys part of the local reality. Of course, every piece of social reality is complex and is articulated with other parts. The challenge is trying to build a bridge between the complexity of social reality and what the project needs to know to avoid serious misunderstandings. There are not many ways to build this kind of bridge: learning to listen to differing points of view, learning to express these views in an understandable way for non-specialists, long and regular exchanges between different specialists, and building mutual trust in these exchanges.

**Studying mountain ethnic groups in Vietnam as catalyst for research in development**

This paper focuses on projects in ethnic mountain areas in northern Vietnam. This a very small focus in comparison with the many agrarian issues faced in South-East Asia. The idea is not to look for situations representing a qualitative point of view. Instead, by addressing the problems of knowledge production from extreme, atypical and marginal situations we can see more clearly the nature and causes of these problems. Agriculture and society among ethnic groups in Vietnam are two marginal axes within South-East Asian studies.
These two axes will be catalysts to highlight other problems of knowledge about agricultural projects encountered elsewhere in South-East Asia².

**Some ‘issues’ to justify the failure of development projects in the ethnic context**

This section describes some issues or topics that are used as evidence of the failures and problems of development projects in ethnic populations in Vietnam. From these focused topics, we can put forward some more general principles that we can apply to other topics that also explain the failures of projects. I discuss 3 topics that are among the most frequent and that are advanced as the main causes of problems in reports of project development and in the scientific literature: language barriers, cultural barriers and participation.

**Language barriers³**

Language barriers are typically summarised as ‘Because ethnic populations don’t understand enough Vietnamese language, they cannot participate (or participate enough) within development projects.’ From my 15 years of anthropological field experience in ethnic villages in many provinces in northern Vietnam, I can observe that most adults can speak enough Vietnamese to understand a project meeting in their village. So even if a few people are not fluent in Vietnamese, this doesn’t significantly affect a project’s implementation and results. Moreover, this assertion of causality between a lack of linguistic knowledge and the participation and performance of a project is not based on any serious, comprehensive and thorough study⁴. It is therefore a preconceived idea that seems obvious to many development officers, local government leaders and researchers.

Because this assumed link of causality is repeated in the vast majority of reports and articles, it has managed to become the norm, even the scientific truth, of projects.

In contrast, anthropological surveys reveal many difficulties in communication between project staff and ethnic populations. For example, in many interactions with state authorities and development projects (the two are often equated by ethnic populations), some ethnic populations say they do not understand Vietnamese, thus allowing them to protect themselves from the intrusion of projects they don’t want. They create a distance in communication with external agents.

The real problem is that they don’t want to speak Vietnamese in certain situations.

---

² Agriculture and mountain ethnic groups are important topics in current research. For example, in the papers presented at this conference, 18 (~35%) concern agricultural matters among ethnic groups in the uplands of Vietnam and Laos.

³ ‘Inability to speak Vietnamese, and some traditional cultural practices, are emphasised as obstacles that prevent ethnic minorities from being better integrated into the economy and taking advantage of the new opportunities provided by the Doi Moi in numerous qualitative studies’ (Baulch et al. 2010: 37).

⁴ ‘... Experiencing language and other cultural barriers causing constrained access to information, education, development initiatives and services’ (van de Fliert et al. 2010: 330).

⁴ Methods of survey most commonly used (e.g. questionnaire, quick survey, participatory rural appraisal, focus group) are not sufficient to adequately describe such situations.
This distancing, evident in all anthropological surveys, must be understood as a form of flexible resistance, creating an appearance of incompetence. However, it is not mentioned in reports of development projects written by international consultants or by Vietnamese experts. In this regard, the weight of political correctness and cultural preconceptions still weighs on the production of data on ethnic societies in Vietnam.

**Cultural barriers**

The vast majority of reports on development show the culture of ethnic ‘minorities’ of Vietnam as an important variable limiting their economic development. However, this assertion is not based on any serious sociological or anthropological surveys. It is only the product of impressions and the integration of hierarchical categories in effect in most Vietnamese social conceptions and media (Nguyen, 2010). None of the authors who argue that the culture of ethnic groups is one of the reasons for their underdevelopment can give a clear definition or scientific concept of culture, or scientific arguments about the cause and effect relationship between a specific ‘culture’ and its level of development.

Some comparisons may seem to confirm this causal link in Vietnam. For example, differences in levels of economic development between the Kinh (demographic majority) and other ethnic groups (minorities) are explained simply as ‘because they have different cultures.’ However, this comparison, which lies at the heart of the causal link, loses its demonstrative power when we compare the same ethnic group, with the same language and culture, in neighbouring countries. For example, the Hmong are ranked at the bottom of the ladder of economic development in Vietnam, as supported by their ‘backward’ cultural behaviours and their ‘lack of openness to modernity’. In contrast, in Thailand and Laos, the Hmong show better integration in agriculture, local commerce and services. In this case, the cultural variable is used to induce two opposite results in two different contexts. To better understand the factors of development, it is necessary to introduce another variable here: the type of relationship between the state and ethnic populations. Without going into details, we can say that the relationships between the Hmong and the state are very different in all three countries.

These remarks on language and culture as supposed explanatory criteria require researchers to broaden their arguments and to better integrate local views on the basis for underdevelopment. They also allow 2 more methodological findings:

---

5 | IBRD / World Bank 2009. This culturalist approach is present in almost all economists’ reports on ethnic groups (Baulch et al. 2008). ‘À la géographie des richesses naturelles s’ajouteriait un facteur culturel à propos, en l’occurrence, des populations ethniques minoritaires dont les croyances et pratiques seraient moins propices à une utilisation rationnelle des ressources productives’ (‘To the geography of natural resources would be added a cultural factor, namely, the ethnic minority populations whose beliefs and practices are less conducive to the rational use of productive resources’) (Nguyen and Trinh 1999).

6 | ‘New policies for “Hunger Eradication and Poverty Reduction” [Program 135, supported by the World Bank] that began in the late 1990s continue to focus on issues such as “nomadism” and “backwardness” as the faults of minorities that prevent them from developing.’ (McElwee 2004: 204).

New dimensions

The researcher (anthropologist or agronomist) must incorporate new dimensions in the analysis of human relationships: for example, the political dimension of social relations. The quality of relations between the state and local people is an important cause. This dimension is always present but is often ‘forgotten’ in the descriptions and analyses. The notion of ‘politics’ is used here in its sociological sense: ‘construction and management of collective human relations in a specified space and time’.

The heuristic advantage of this concept is that it forces us to take into account the phenomena of tension, conflict, negotiation and thus power and authority in all human interactions. Flexible resistance of certain ethnic populations (‘I don’t want to speak their language in this situation’) dealing with external pressures (projects imposed without local demand and sometimes against needs) is typically an act of ‘everyday politics’. This type of resistance is expressed without a leader, an institution (no formal or official group), promotion or the need to justify it.

Willingness to deal with changes

These remarks also raise questions about an important dimension that is often neglected in the description and analysis of ethnic populations: their willingness and desire to deal with all the changes that affect them.

The official reports of the Vietnamese ministries and agencies, reports of international development projects, and books and articles by development specialists make very little mention of the wishes, concepts of development and conceptions of wellbeing among the targeted populations. This literature lends the impression that these people are largely without will and conceptions. The empirical match between these texts and reality is very low.

I quote a few lines from a text published in 2010 by a group of authors, most of whom are attending this conference. The introduction concentrates in a few lines most of the explanatory arguments advanced to justify difficulties in the economic development of ethnic populations in mountain areas of Vietnam (van de Fliert et al. 2010):

‘Ethnic minority communities located in remote and marginal mountainous areas have largely been unable to benefit from the developments as a result of a range of complex factors aggravated by a communication disconnection with the mainstream agencies of development … . Vietnam has 53 ethnic minority groups, accounting for 12.6% of the total population, who for the greater part inhabit the mountainous areas in the North West and North East regions and the Central Highlands. In 2006, 52% of ethnic minority people were reported to live in poverty in comparison with 10% of the Kinh majority group … . Main reasons for this disparity are, in summary, differences in assets, capacity and voice. These relate to ethnic minorities having fewer physical (land, capital, credit) and social (education, health, access to services) assets, being mostly located in geographic remote areas with limited physical mobility, and experiencing language and other cultural barriers causing constrained access to information, education, development initiatives and services … .’
Here I would like to introduce a few angles to analyse arguments that justify the difficulties of ethnic groups in development:

‘Ethnic minority communities located in remote and marginal mountainous areas have largely been unable to benefit from the developments ...’. Geographical and political distance from the centre could explain their ‘inability’ to benefit from development. It would be interesting to have the perspective of villagers (with deep surveys) on what ‘development’ means for them. In all cases, studies see ethnic people only from the perspective of the centre: the state, the national capital, the provincial capital, the Kinh majority. This situation of political and administrative control is a real problem when we know that in all the provinces of northern Vietnam, mountain ethnic groups form a large majority.

‘... A communication disconnection with the mainstream agencies of development.’ Indeed, there are major communication problems in all development projects, especially in ethnic areas. But, of course, we cannot attribute the responsibility for these problems only to the ethnic populations. Development agencies and Vietnamese authorities, as essential partners in all projects, also have a role. To discuss the direct responsibility of development agencies and the authorities in the malfunction of projects requires them to agree to talk about ‘everyday politics’. But development agencies and authorities try to avoid everyday politics at all costs. Under these conditions, how can we understand these situations without basic data on the relationships between the social groups interacting in the projects?

Van de Fliert et al. (2010) explain or justify the disparities in terms of development standards by:

- fewer physical (land, capital, credit) and social (education, health, access to services) assets
- concentration in remote areas with limited physical mobility
- language and other cultural barriers restricting access to information, education, development initiatives and services.

Some of these assertions are contradicted by local realities. For example, in mountainous areas, the area of land, and even arable land, per household is much greater than in the deltas of the Red and Mekong rivers (World Bank 2007). The set of criteria presented, with the backing of references from international donors (as scientific guarantee?), are covered under natural conditions (located in remote areas), or these situations are imperative for ethnic populations (‘having fewer physical ... and social ... assets, ... and experiencing language and other cultural barriers causing constrained access to information, education, development initiatives and services.’)

In these criteria, we note the underlying idea of a form of passivity among ethnic populations.

---

8 In Lao Cai province, 65% of the population are ethnic groups; Dien Bien Phu province, 79%; Ha Giang, 80%; Lai Chau, 86%. Thus, we must question the expression ‘ethnic minority’ at least at the provincial and district level.
This idea of passivity is often euphemistic in the official discourse of donors, although it is expressed more directly in Vietnamese texts.\(^9\)

What is the level of consistency (or reliability)\(^{10}\) between these criteria and their explanatory capacity and the local realities to which they refer? We do not have enough space to answer this here, but this should be one of the first questions to ask when we evaluate and use field data or analyses produced by other researchers.

In many situations, ethnic populations must accept what is imposed by projects. Moreover, has anyone ever seen a project that asks the target populations whether or not they want the project as it is designed? But formal acceptance does not mean full respect for the objectives, purposes and methods of the project. In most projects (when possible), local people will modify it to suit their needs. Such transformations (‘misappropriations’) of projects are among the most remarkable signs of participation. But the project will not record these adaptations (even if they are effective), because they are outside the terms of reference and the logical framework. Yet despite the failure to report most such transformations, they are key to adapting a project to local capacities. In this context, de Certeau et al. (1981) speak of ‘tactics of compromise’ as opposed to ‘strategies to impose’.

It is necessary to grasp the game of power and authority between the different stakeholders in order to understand the articulated reality of a development project: that is, all social, technical, economic, political and symbolic interactions that construct and transform the project.

Van de Fliert et al. (2010) suggest political relations as ‘differences in assets, capacity and voice’. ‘Voice’ is a direct reference to the possibilities of expression, and making one’s voice heard is one of the actions of everyday politics. The notion of ‘voice’ is articulated in the notions of ‘loyalty’ (compliance without discussion) and ‘exit’ (rejection of constraints by avoidance and distancing) (Hirschman 1970). Voice is also a key to the participatory approach so often put forward in projects.

**Participation as an action in everyday politics**

I also discuss the use of the terms ‘participation’ and ‘participatory approach’ to justify the role that the project wants to play in the target populations.

In the case of CA projects, the notion of participation is essential, because farmers must have strong confidence in a project in order to radically change the way they think and act. Here, efficiency can come only from an active and motivated participation. For this reason, it is necessary to distinguish between the public discourse on participation to satisfy donors and a more contextualized approach, probably less formal and more flexible, about real modes of involvement in a project.

---

\(^9\) In Vietnam there is also some direct pejorative characterisation of ethnic groups by Vietnamese Kinh. (Nguyen 2010; Culas 2010, 2012; Culas et al. 2012).

\(^{10}\) The epistemology of anthropology usually talks about ‘empirical adequacy’ (Olivier de Sardan 2008).
The notion of participation and all its variations was imposed in the early 2000s by the IMF and the World Bank, in association with notions of ‘ownership’, ‘accountability’ and ‘governance’, in Poverty Reduction Strategy Papers. Thereafter, the vast majority of Vietnamese projects, even top-down projects such as the ‘Programme for Socio-economic Development in Communes faced with Extreme Difficulties’ in Vietnam, included a participatory component. But we must not confuse the public expression of participation by a project and the real practices. Much of the discourse on participation is only intended to satisfy the demands of donors, without being practically connected with the local reality of the project. International donors impose participation on states as a condition of aid. States then impose it on their projects and perhaps their population. This top-down imposition is contrary to the idea of participation, and yet is the usual form of the design and installation of projects in Vietnam.

When we study how development projects are designed, we see that they are based on a very low and still insufficient set of knowledge of local situations. For example, no project is designed on the basis of discussion, exchange and negotiation with the target populations. Development officers, donors and the state decide on the objectives and methods of the project. All project objectives respond first and foremost to national and international constraints that are completely external to the local situations that the project is designed to transform. Moreover, the modes of participation are themselves determined by project experts and not by the population itself. Thus, the use of the term ‘participation’ must be questioned in depth in the vast majority of projects.

One of the bases of research in social sciences is that collective action is part of a panel of specific norms, those of different local actors (Chauveau et al. 2001; Olivier de Sardan 2009): state, private companies, development projects, NGOs, farmers etc. Collective action makes sense only in the negotiation or articulation of conflict with these different norms. Participation (positive or negative) is only one aspect of the interaction between actors from different groups. If we view collective action only through a single norm—here the Vietnamese government or development project—we cannot understand the extended sense of collective action. It is possible to take the norm of the state or development project as a reference, but it should not be forgotten that this norm is locally connected and is often in competition with others—less shown, less established, less verbalized but equally decisive in the choice of local actors.

These issues illustrate the main reasons for the economic underdevelopment of mountain ethnic groups. But other themes and arguments could be analysed with the same empirical and critical approach to assess their empirical match with observed reality (Olivier de Sardan 2008).

---

11 Also known as ‘P135’. Approved by Decision 135/1998/QDTTg, Prime Minister, 31 Jul 1998.
Provisional conclusion

An important part of the difficulties and failures of development projects derives, directly or indirectly, from daily political configurations that express or interfere with projects. Whether we consider tensions between the president of the people’s committee of a commune and the first secretary of the party; the decision by Vietnamese (Kinh) officials to purchase land in a totally ethnic commune; the refusal by peasants to speak Vietnamese; or many other cases: we are dealing with the expression of everyday politics. Failure to understand such political situations and the actors involved in a project significantly increases the risk of problems and failure. Everyday politics exists everywhere in all forms of negotiation, claim, application, association, tension, conflict and even ‘exit’ (that is, refusal to communicate with local officials).

When agronomists begin a project, they are interested in the details: the context (climate, soil etc.), agricultural practices, local knowledge and perceptions.

Any development project is based on human and social interactions between different strategic groups 12 (development officers, local authorities, private companies, farmers). For the proper functioning of a project, it is necessary to examine the practices and local customs in relation to social relations, in terms of local knowledge and perceptions relating to projects past and present.

With this knowledge, it should be possible to create more effective projects by integrating local interactions in the project: collective human interactions expressed through relations of authority and power and the creation of informal groups to achieve certain strategic point targets punctually (Olivier de Sardan 2003). Some questions and even basic knowledge of the aspects of everyday politics can help greatly in the realization of an innovative agricultural project.

Keywords

Anthropology of development project, empirical approach, uplands, ethnic groups, ethnic minorities, Vietnam

Bibliography


12 For detail see Olivier de Sardan (2003).


Nguyễn QP, Trinh QT. 1999. May van de ly luan va thuc tien ve dan toc va quan he dan toc o Vietnam (Some theoretical and practical issues on ethnicity and ethnic relations in Vietnam). Nha xuat ban Chinh Tri Quoc Gia (Maison d’édition Politique Nationale), Hanoi.


Framework, dynamics and challenges of transdisciplinary research-for-development on sustainable land management in the north-western highlands of Vietnam

Elske van de Fliert*1, Pham Thi Sen2, Oleg Nicetic1, and Le Quoc Doanh2

1 Centre for Communication and Social Change, School for Journalism and Communication, University of Queensland, Brisbane, Queensland 4072, Australia
2 Northern Mountainous Agriculture and Forestry Science Institute, Phu Tho, Vietnam

*Corresponding author: e.vandefliert@uq.edu.au

The complex dynamics of rural communities and the major economic and environmental threats looming worldwide make it necessary to link science with farmers’ realities to achieve sustainable change (e.g. Pohl 2005; Lieblein et al. 2008; Van de Fliert et al. 2010). Biophysical, agricultural, economic and social scientists, development practitioners and communities need a shared understanding of these complex realities to enable collaborative and complementary learning. The management of sloping agricultural land in the north-western highlands of Vietnam, a relatively poor and ethnically diverse area, is a complex situation in which a transdisciplinary approach is needed to find sustainable solutions that are acceptable to the local communities. Since the 1990s, production of maize has been the major driver of rural development in north-western Vietnam, resulting in significant increases in farmers’ income, but at the same time causing severe soil erosion. Although government and development organisations have been supporting research that makes effective soil conservation techniques available, none of these techniques have been widely taken up by farmers.

A project funded by ACIAR in north-western Vietnam has been addressing this disparity between the availability of research outputs and their on-farm use within a transdisciplinary and transinstitutional framework. This framework emphasises the importance of adaptive research involving the collaboration of farming communities, local government, extension services and biophysical and social scientists. Technical trials evaluating and adapting technologies on farm within the specific local agroecological and socioeconomic context are coupled with the design and testing of ways to share innovations on a larger scale. Through annual workshops and field-based participatory monitoring and evaluation, research is developed and results are analysed in consideration of the viewpoints of all stakeholders. Linkages with the provincial extension system were established early on, and mechanisms were developed to support outreach of the results beyond the scope of the project.

The project runs from early 2009 until the end of 2013.
Regular reviews and improvements have kept the framework effective under changing conditions. Although the project still faces challenges to scale up sustainable agricultural practices, stakeholder participation has improved significantly and the use of sustainable farming practices in the project locations has been successfully promoted.

Our experiences show that all stakeholders need to be engaged in the development of a shared methodology. It takes a considerable amount of time to establish the required willingness and capacity of transdisciplinary research teams to function effectively. Our experience shows that it is easier to manage these collaborative structures at the field level than to establish institutional mechanisms that support transdisciplinary and transinstitutional collaboration. Moreover, there is often a conflict between the goals of the funding bodies and the requirements of implementing transdisciplinary research-for-development on the ground.

**Keywords**

Transdisciplinary collaboration; research for development; sustainable agriculture

**References**


Assessing the contribution of participatory approaches to sustainable impacts of agricultural research-for-development in the northwest highlands of Vietnam

Nguyen Huu Nhuan*1,2, Oleg Nicetic1, Lauren Hinthorne1 and Elske van de Fliert1

1 Centre for Communication and Social Change, School for Journalism and Communication, University of Queensland, Brisbane, Queensland 4072, Australia.
2 Faculty of Economics and Rural Development, Hanoi University of Agriculture, Gia Lam, Hanoi, Vietnam

*Corresponding author: huunhuan.nguyen@uqconnect.edu.au

The northwest highlands of Vietnam are characterised by high ethnic diversity and typical mountainous topography. The highlands include six provinces with a total area of 5.07 million ha, which accounts for 15.32% of the whole country (NOMAFSI, 2012). These provinces are home to over 30 ethnic minority groups. The highlands are diverse not only in culture and ethnicity, but also in their degree of connectedness to markets. A harsh natural setting, increasing population pressure and low education of local people are major causes of unsustainable management of agroecosystems (Van de Fliert, 2008). Moreover, extension programs have not paid adequate attention to the participation of the local communities and their knowledge (Thai et al., 2011). These factors have led to unsustainable development in the northwest highlands.

In recognition of these problems, the Vietnamese government and international development agencies (e.g. World Bank, FAO, UNDP, ACIAR, CIRAD) have invested heavily since the early 1990s through various social and economic development policies and research initiatives. Most agricultural research projects have aimed at economic development through increasing agricultural production and improving market engagement. However, research-for-development, targeting the immediate use of research outputs for development purposes, appeared in the late 2000s. Participatory approaches have been adopted in several of these projects in an attempt to better link research with development, but with varying approaches towards stakeholder engagement, ranging from using farmers as field labourers to involving them as co-researchers. It is generally assumed, but increasingly debated and mostly not proven, that farmer participation enhances the applicability of research outputs. Understanding the contribution of a participatory approach towards sustainable impacts will be very important for informing agricultural research-for-development strategies in the future.

Assessing the impact of agricultural research and the contribution of a participatory approach in research projects in the northwest highlands remains problematic in terms of both objectives and methods.
Firstly, most agricultural research initiatives involve only short-term impact assessment, while research-for-development often takes a long time to achieve results.

Secondly, current impact assessment practices tend to focus more on economic impacts and ignore human, social, physical and natural impacts, which are also vital capital components of a sustainable livelihood.

Thirdly, although various participatory tools have been used in impact assessment, ethnic diversity means that in many cases local people have not been empowered, owing to gaps in the researchers’ understanding of social culture, languages and perceptions.

Fourthly, the results and findings of current impact assessment approaches have sometimes been misleading, attributing greater impact to a single project and ignoring the synergistic effects of simultaneous initiatives in the same area.

Finally, the impact indicators and feedback mechanisms currently used for impact assessment often measure the returns on investment or the cost-effectiveness for donor organisations rather than the sustainability of these impacts for key stakeholders. These limitations have led to unconvincing evidence showing how and why specific research and development approaches have contributed to (or, rather, failed to deliver) sustainable impacts.

As in any development activity, assessing the impact of agricultural research projects is crucial to sustainable development (Cromwell et al., 2001; Krall et al., 2003). The selection of an appropriate impact assessment method for a particular project will help to achieve good indicators at different levels of contributions (Meinzen-Dick et al., 2003; Tran et al., 2008). The results of impact assessment not only are crucial for learning about the impacts of research-for-development, but also offer suggestions for the formulation of appropriate measures and strategies towards sustainable development of the target areas (Cramb et al., 2003; Krall et al., 2003). A holistic approach towards assessing the impacts of agricultural research-for-development, underpinned by participatory communication strategies, is important to supporting sustainable social change.

This paper reviews existing impact assessment approaches for agricultural research projects as practised since the 1990s in the northwest highlands, and discusses their strengths and weaknesses. It concludes with a suggestion for an alternative impact assessment framework for agricultural research-for-development projects that is developed from a comprehensive livelihoods perspective in a region with variable stages of agricultural development and social change.

Keywords
Impact assessment; agroecosystems; research-for-development
References


Chapter 2

Design of Agricultural Systems

Subtopic 2

Adaptive research for development: methods, tools, indicators

Vietnam
CA experiments on sloping lands

D. Hauswirth, Van Chan, 08/2011
Keynote 3: Adaptation of direct-sowing mulch-based cropping systems for annual cash crop production in Cambodian rainfed uplands

Stéphane Boulakia*ab, Stéphane Chabierskiab, Phûlly Koubc, Sona Sanb, Rada Kongb, Vira Lengb, Veng Sarb, Kimchhorn Chhitb, Lucien Séguyd

a CIRAD, UPR SIA, F-34398 Montpellier, France
b PADAC project, General Directorate of Agriculture, Ministry of Agriculture, Forestry and Fisheries, Phnom Penh, Cambodia
c Cambodian Rubber Research Institute, General Directorate of Rubber Plantation, Ministry of Agriculture, Forestry and Fisheries, Phnom Penh, Cambodia
d Agroecoriz, Limoges, France

*Corresponding author: stephane.boulakia@cirad.fr

Abstract

The production of annual cash crops (soybean, maize, cassava) in upland rainfed agriculture has been practised for more than 60 years in Cambodia. Today it is an important dimension in the development of smallholder agriculture on the western and northern pioneer fronts. Current tillage-based cropping systems induce soil depletion, weakening the production systems. A 9-year R&D program, initiated in 2004, has implemented the DATE methodology (Diagnosis, Design, Assessment, Training and Extension) to adapt direct-sowing mulch-based cropping alternatives for the sustainable production of soybean, maize and cassava ‘on-farm, with and for farmers’. The cropping systems that have developed integrate cover crops for biomass input to allow a rapid improvement of production capacity, even when instituted on severely degraded soil, setting the technical basis for sustainable agriculture that needs limited inputs of agrochemicals and that is adapted to smallholders’ conditions.

Keywords

Conservation agriculture, DMC, soybean, maize, cassava, Cambodia, DATE

1. Introduction

In Cambodia, upland rainfed agriculture with annual crops branched off from the dominant lowland rainfed rice-based systems in the 1950s (Delvert 1961).
Farmers of Kampong Cham province began clearing dense forests on low basaltic plateaux to grow pulse-based (mung bean, *Vigna radiata*; soybean, *Glycine max*), market-oriented cropping systems.

In the 1980s and 1990s, this land conquest, by both annual and perennial crops (cashew, *Anarcardium occidentale*; rubber, *Hevea brasiliensis*), restarted, despite continuing fights between government forces and Khmer Rouge guerrillas and the presence of land mines.

After the restoration of peace, the area of annual upland crops soared from 120,000 ha in 2000 to about 800,000 ha in 2012. This development has been promoted by migration from populated central regions to forested peripheral regions, the illegal clearing of forests, and strong regional demand for maize, cassava and soybean (Boulakia et al. 2011).

As in Lao PDR (Lestrelin et al. 2012), cropping systems developed by Cambodian farmers are based on intensive soil tillage and monocropping, and induce rapid soil degradation (Séguy et al. 2008; Tivet et al. 2012). To reverse the degradation, the Cambodian Ministry of Agriculture has hosted an R&D program led by CIRAD and funded by the AFD since 2004 and by USAID since 2010, directed at local smallholders and based on conservation agriculture (CA), also referred to as direct-sowing mulch-based cropping (DMC) systems.

The program has used the DATE methodology (Diagnosis, Design, Assessment, Training and Extension) to design alternative DMC systems in collaboration with local farmers in Kampong Cham province, in the central east, and in Battambang province, in the west, two regions of important but contrasted development of annual upland crops.

This paper presents the co-development of DMC systems in the two regions. It illustrates how DATE can be used to create innovation through dialogue between, on the one hand, researchers and technicians, acting as ‘permissive guards’ of the DMC ‘technology essence’ (i.e. its properties coming from the combined effects of minimum soil disturbance, permanent soil cover and crop rotations or associations; Kassam et al. 2009); and, on the other hand, farmers, who want to reduce costs and simplify their practices. Such a dialogue can lead to the adaptation of DMC technologies to local environments and to the socioeconomic capacities of smallholders, and create measures that can facilitate adoption.

2. Materials and methods

2.1. Sites

Kampong Cham (KC) and Battambang (BTG) were chosen for their important share of upland annual crops in the production systems (Table 1).
Table 1. Location, biophysical parameters and dominant upland cropping systems in Kampong Cham and Battambang provinces.

<table>
<thead>
<tr>
<th>Location</th>
<th>Kampong Cham</th>
<th>Battambang</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Dambe and Ponhea Krek districts</td>
<td>Rattanak Mondul district</td>
</tr>
<tr>
<td>North-western extent</td>
<td>11°58’N, 105°47’E</td>
<td>13°00’N, 102°46’E</td>
</tr>
<tr>
<td>South-eastern extent</td>
<td>11°49’N, 105°53’E</td>
<td>12°54’N, 102°57’E</td>
</tr>
<tr>
<td>Altitude</td>
<td>50 m</td>
<td>100 m</td>
</tr>
<tr>
<td>Climate</td>
<td>6–7-month rainy season (April–November); 1200–1800 mm Average temperature 28°C</td>
<td></td>
</tr>
<tr>
<td>Soil type</td>
<td>Oxisol and Vertisol (on basalt)</td>
<td>Mollisol</td>
</tr>
<tr>
<td>% organic matter (0–10 cm)</td>
<td>2.0%–3.0%; 3.0%–4.0%</td>
<td>1.5%–2.5%</td>
</tr>
<tr>
<td>pH</td>
<td>4.5–5.0; 5.0–5.5</td>
<td>6.5–8.0</td>
</tr>
<tr>
<td>Texture</td>
<td>Clay</td>
<td>Silty clay</td>
</tr>
<tr>
<td>Reference cropping system (disc ploughing before each crop)</td>
<td>Cassava monocropping</td>
<td>Maize</td>
</tr>
<tr>
<td></td>
<td>Sesame / soybean annual succession</td>
<td>Maize / maize annual succession</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mung bean / maize annual succession</td>
</tr>
<tr>
<td>Main market destination</td>
<td>Vietnam: animal feed, bioethanol</td>
<td>Thailand: animal feed</td>
</tr>
</tbody>
</table>

2.2. DATE (Diagnosis, Design, Assessment, Training and Extension)

The DATE approach (Séguy et al. 1998, 2006; Husson et al., unpublished) allows one to adapt a large number of DMC innovations to local biophysical and socioeconomic conditions while comparing the performance over time with conventional practices. Innovations are aligned to the same production goals of farmers, following a priori the best market opportunity, and progressively introduce and develop options for diversification.

DATE is a holistic approach, built on 4 main components (Fig. 1):

An initial rapid rural appraisal to provide a multilevel systemic analysis of the agricultural situation and rural context:

• at the plot level—with reference cropping systems (technical description, agronomic diagnosis, economic performance) for each agroecosystem

• at the farm level—in which production systems are analysed and partitioned into a simplified, operational ‘farm typology’ (for further understanding of different adoption capacities)

• in the farm environment—evaluating market and price evolution, inputs and labour costs, credit access, land tenure and opportunities for off-farm activities.

‘Matrices’ of cropping systems (crops and cover sequences or associations and type of soil management are systematically crossed with different levels of fertilisers) implemented in each agroecosystem.
Elementary plots are not replicated, and measure 200 m² (only the farmers’ reference practices can be used as a control if the experimental site presents an obvious gradient of heterogeneity). At this stage, the first practical application of the systems is conducted with power tillers. The ‘system’ applied in some treatments can evolve from year to year in order to test and assess new approaches. Optimisation of these first drafts can mobilise thematic trials (cultivar, topdressing, weed control). Themes are determined by the systems’ needs and can be studied through the collection of treatments with control test or with complete replication.

Full-scale application of the most promising systems over several years (2000 - 6000 m² per plot) by researchers and technicians. In this second loop of improvement, feedback on practicability (mechanisation, cover crop management, weed control) and technical and economic performances is gathered. Such plots, located in the middle of communities and well known for their poor initial performance, also constitute the demonstration of the technicians’ and agronomists’ skills, a necessary condition to setting mutual trust.

In parallel, a pilot extension network is progressively implemented with volunteer smallholders (usually following fields days). It aims mainly at tuning the practices through farmer feedback; assessing the evolution of the technical and economic performance; and reviewing the constraints in order to suggest and test measures to facilitate and scale up the adoption process. At this stage, a more precise record of cost and labour is made on a subsample of representative farms.

**Figure 1.** Main stages and organisation of the DATE approach as implemented in Cambodia.
2.3. Experimentation and demonstration bases

2.3.1. Tillage-based references and DMC cropping systems

Three tillage-based cropping systems were assessed as references: (1) annual succession of sesame / soybean, regularly practised in KC on red Oxisol but abandoned on black Vertisol for (2) cassava (*Manihot esculenta*) monocropping during 2005–2007; and (3) maize (*Zea mays*)-based monocropping, which is the dominant practice in Battambang. Each crop is preceded by a shallow disc ploughing (disc harrow with 6 or 7 discs, pulled by a 47–63 kW tractor belonging to a contractor).

The first DMC- (or minimum tillage: MT-) based alternatives were based on these quasi-monocropping systems, and evolved, under continuous assessment of economic performance, towards increased biomass inputs (crop residues + cover crop mulch) and species diversity. The alternatives were developed around soybean in annual succession or in biannual rotations with maize (DMC maize // soybean) or cassava (MT cassava // soybean); around cassava in annual association (MT cassava) or in biannual rotation with maize (MT maize // cassava); and around maize in annual succession (DMC maize). Initially grown under strict DMC (minimum soil disturbance), all cassava crops were preceded by MT since 2010 with a ‘striping’ of the planting line by chisel plough (1-prong combine with a disc coulter, every 0.80 m) to 15-cm depth.

2.3.2. Matrices

Two matrices have been followed in Kampong Cham: KC-R on red Oxisol (11°57’30’’N, 105°48’32’’E) since 2004, and KC-B on black Vertisol (12°19’29’’N, 105°12’35’’E) since 2006. Rotation-based systems are implemented on 2 plots in permutation in order to model the 2 annual components of the systems every year (Table 2).

Each cropping system used 3 levels of fertiliser: F0 (NPK from 0–0–0 to 23–0–0 for all main crops), F1 (23–13–25 on soybean, 70–13–25 on maize, 70–13–50 on cassava) and F2 (23–35–50 on soybean, 90–35–50 on maize, 90–35–75 on cassava).

2.3.3. Demonstration plots network

Nine demonstration plots supported scaled-up tests and assessments (Table 3). The plots were managed as in Table 2 with fertiliser at F1.

2.4. Evolution of farmers’ network

2.4.1. Support in access to technologies

The project provided incentives, including interest-free credit for the purchase of inputs (fertilisers, herbicides, cover crop seeds) and access to machinery (no-till planter, cover crop roller, 6–7-m boom sprayer) at rates charged for conventional practices.
| Table 2. Crop and cover crop sequences tillage practices in the KC-R and KC-B matrices. |

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Plough sesame / soybean</td>
<td>Si / Gm</td>
<td>Si / Gm</td>
<td>Si / Gm</td>
<td>Si / Gm</td>
<td>Si / Gm</td>
<td>Si / Gm</td>
<td>Si / Gm</td>
<td>Si / Gm</td>
<td>Si / Gm</td>
</tr>
<tr>
<td>DMC soybean</td>
<td>BM Ec / Gm</td>
<td>BM Ec / Gm</td>
<td>BM Ec / Gm</td>
<td>BM Ec / Gm</td>
<td>- / Gm + Br</td>
<td>- / Gm + Sg+Sb/g</td>
<td>- / Gm+Sg+Sb/g</td>
<td>- / Gm+Sg+Sb/g</td>
<td>- / Gm+Sg+Ha</td>
</tr>
<tr>
<td>DMC maize // soybean</td>
<td>Other DMC management</td>
<td>- / Zm + Br</td>
<td>- / Gm + Sg</td>
<td>- / Zm + Br</td>
<td>- / Gm + Sg</td>
<td>- / Zm + Br</td>
<td>- / Gm + Sg</td>
<td>- / Zm + Br</td>
<td>- / Gm + Sg + Ha</td>
</tr>
<tr>
<td>DMC x maize</td>
<td>Other DMC management</td>
<td>BM Ec / Gm + Sg</td>
<td>- / Zm + Br</td>
<td>- / Gm + Sg</td>
<td>- / Zm + Br</td>
<td>- / Gm + Sg</td>
<td>- / Zm + Br</td>
<td>- / Gm + Sg</td>
<td>- / Gm + Sg + Ha</td>
</tr>
<tr>
<td>Plough sesame / soybean</td>
<td>Si / Gm by plot’s owner</td>
<td>Si / Gm</td>
<td>Si / Gm</td>
<td>Si / Gm</td>
<td>Si / Gm</td>
<td>Si / Gm</td>
<td>Si / Gm</td>
<td>Si / Gm</td>
<td>Si / Gm</td>
</tr>
<tr>
<td>DMC soybean</td>
<td>BM Ec / Gm</td>
<td>BM Ec / Gm</td>
<td>BM Ec + Gc / Zm + Br</td>
<td>- / Gm + Sg</td>
<td>- / Gm+Sg+Sb/g</td>
<td>- / Gm+Sg+Sb/g</td>
<td>- / Gm+Sg+Sb/g</td>
<td>- / Gm+Sg+Sb/g</td>
<td>- / Gm+Sg+Sb/g</td>
</tr>
<tr>
<td>DMC maize // soybean</td>
<td>- / Gm + Sg</td>
<td>- / Gm + Sg</td>
<td>- / Gm + Sg</td>
<td>- / Gm + Sg</td>
<td>- / Gm + Sg</td>
<td>- / Gm + Sg</td>
<td>- / Gm + Sg</td>
<td>- / Gm + Sg</td>
<td>- / Gm + Sg</td>
</tr>
<tr>
<td>MT x maize // soybean</td>
<td>Me + Br</td>
<td>- / Gm + Br</td>
<td>Me + Br</td>
<td>- / Gm + Br</td>
<td>Me + Br</td>
<td>- / Gm + Br</td>
<td>Me + Br</td>
<td>- / Gm + Br</td>
<td>Me + Br</td>
</tr>
<tr>
<td>MT cassava</td>
<td>Me + Sg</td>
<td>Me + Sg</td>
<td>Me + Sg</td>
<td>Me + Sg</td>
<td>Me + Sg</td>
<td>Me + Sg</td>
<td>Me + Sg</td>
<td>Me + Sg</td>
<td>Me + Sg</td>
</tr>
<tr>
<td>MT maize // cassava</td>
<td>Other DMC management</td>
<td>- / Zm + Sg</td>
<td>Me + Sg</td>
<td>- / Zm + Sg</td>
<td>Me + Sg</td>
<td>- / Zm + Sg</td>
<td>Me + Sg</td>
<td>- / Zm + Sg</td>
<td>Me + Sg</td>
</tr>
</tbody>
</table>

- Disc ploughing before each crop cycle. ■ MT by strip tillage with chisel plow  □ DMC, minimum soil disturbance, crops and cover crops established by 2-row no till planter (Fitarelli)

Upper half of a cell shows 1st part of the rainy season (April–June); lower half, 2nd part (July–November)

Br, *Brachiaria ruziziensis*; Cc, *Cajanun cajan* (pigeon pea); Ec, *Eleusine coracana* (finger millet); Gm, *Glycine max* (soybean); Ha, *Helianthus annuus* (sunflower), Me, *Manihot esculenta* (cassava); Pg, *Pennisetum glaucum* (pearl millet); Sb/g, *Sorghum bicolor* or *S. guineensis*; Sg, *Stylosanthes guianensis*; Si, *Sesamum indicum* (sesame); Zm, *Zea mays* (maize).

BM Biomass—the following species or association is grown only to add biomass and is terminated by rolling plus herbicide application (glyphosate + 2,4-D amine) 60–75 days after sowing.

‘+’ Association of species, early with maize and cassava (<20 days after sowing), late with soybean (at beginning of defoliation).

‘-’ Growth period, during the first part of the rainy season, of the cover crop species associated with the main crop during the previous year. If this cover crop has poor density at the end of the dry season (April), it can be oversown with biomass species such as finger millet, pearl millet, sorghum, pearl millet + pigeon pea or pearl millet + *Crotalaria juncea*. This problem occurs frequently with the cover crop species grown with soybean.
Table 3. Demonstration plots list, soil type, DMC used and period of operation.

<table>
<thead>
<tr>
<th>Plot</th>
<th>Soil type</th>
<th>Cropping systems</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kampong Cham R1</td>
<td>Red Oxisol</td>
<td>DMC maize // soybean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kampong Cham R2</td>
<td>Red Oxisol</td>
<td>DMC maize // soybean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kampong Cham R3</td>
<td>Red Oxisol</td>
<td>DMC maize // soybean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kampong Cham R4</td>
<td>Red Oxisol</td>
<td>MT maize // cassava</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kampong Cham B1</td>
<td>Vertisol</td>
<td>MT maize // cassava</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kampong Cham B2</td>
<td>Vertisol</td>
<td>MT maize // cassava</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kampong Cham B3</td>
<td>Vertisol</td>
<td>MT cassava</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battambang 1</td>
<td>Mollisol</td>
<td>DMC maize // soybean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battambang 2</td>
<td>Mollisol</td>
<td>DMC maize // soybean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In KC, most smallholders initially faced serious soil degradation. It was therefore decided to implement a method of credit cost alleviation in the first 2 years, based on crop yield: in a way, an indirect subsidy in soil capital recovery.

This subsidy approach can also be used to compensate for project mismanagement (technicians and researchers are also in a learning process!) and technical recommendations that impose extra costs without any observed or expected benefits.

2.4.2. Dimension and evolution of the pilot extension network

The pilot farmers’ network was established in 5 villages in KC and in 4 villages in Battambang (Table 4a, b). In parallel, reference plots were monitored in each region: 30 plots (total area of 20 ha) in KC and 20 plots (46 ha) in Battambang.
Table 4a. Number of households, number of plots, area per household and area per DMC system of the pilot extension network in Kampong Cham.

<table>
<thead>
<tr>
<th>Year of adoption:</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Households</td>
<td>78</td>
<td>174</td>
<td>223</td>
<td>134</td>
</tr>
<tr>
<td>Area (ha)</td>
<td>51.8</td>
<td>129.9</td>
<td>171.6</td>
<td>98.2</td>
</tr>
<tr>
<td>Area / household (ha)</td>
<td>0.66</td>
<td>0.75</td>
<td>0.77</td>
<td>0.73</td>
</tr>
</tbody>
</table>

1st year
- **System**: Me + Sg, Me + Sg, Me + Sg, Me + Sg
- **Plots**: 83, 90, 117, 35
- **Area (ha)**: 47.4, 47.8, 73.7, 24.5
- **Total area (ha)**: 51.8

2nd year
- **System**: Me + Sg, Me + Sg, Me + Sg
- **Plots**: 9, 148, 51
- **Area (ha)**: 4.6, 79.5, 26.4
- **Total area (ha)**: 26.2

3rd year
- **System**: Me + Sg, Me + Sg
- **Plots**: 31, 28
- **Area (ha)**: 18.4, 10.7
- **Total area (ha)**: 18.4

4th year
- **System**: Me + Sg
- **Plots**: 17
- **Area (ha)**: 9.6
- **Total area (ha)**: 13.5

See Table 2 for abbreviations.
Table 4b. Number of households, number of plots, area per household and area per DMC system of the pilot extension network in Battambang.

<table>
<thead>
<tr>
<th>Year of adoption</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Households</td>
<td>5</td>
<td>25</td>
<td>29</td>
<td>56</td>
</tr>
<tr>
<td>Area (ha)</td>
<td>4.6</td>
<td>31.8</td>
<td>49.7</td>
<td>141.1</td>
</tr>
<tr>
<td>Area / household (ha)</td>
<td>0.92</td>
<td>1.27</td>
<td>1.71</td>
<td>2.52</td>
</tr>
<tr>
<td>1st year System</td>
<td>BM Ec / Zm + Sg</td>
<td>BM Ec / Zm + Sg</td>
<td>BM Ec / Zm + Cc</td>
<td>BM Ec / Zm + Cc</td>
</tr>
<tr>
<td>Plots</td>
<td>5</td>
<td>20</td>
<td>12</td>
<td>44</td>
</tr>
<tr>
<td>Area (ha)</td>
<td>4.6</td>
<td>28.2</td>
<td>26.0</td>
<td>106.2</td>
</tr>
<tr>
<td>2nd year System</td>
<td>Zm + Sg</td>
<td>Zm + Cc</td>
<td>Zm + Cc</td>
<td></td>
</tr>
<tr>
<td>Plots</td>
<td>5</td>
<td>16</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Area (ha)</td>
<td>3.6</td>
<td>20.7</td>
<td>19.2</td>
<td></td>
</tr>
<tr>
<td>3rd year System</td>
<td>Zm + Cc</td>
<td>Zm + Cc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plots</td>
<td>3</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area (ha)</td>
<td>3.0</td>
<td>14.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4th year System</td>
<td>Zm + Cc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plots</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area (ha)</td>
<td>1.3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

See Table 2 for abbreviations.

3. Results

3.1. Cropping systems performance

3.1.1. Matrix plots

At KC-R, yields in ‘plough sesame / soybean’ were low and variable (345–1090 kg ha⁻¹). Yields in ‘DMC soybean’ also fluctuated (720–1685 kg ha⁻¹), reflecting the climate-dependent and irregular inputs of biomass, which are linked to the short-term cropping of biomass and later on to the broadcast sowing of *Stylosanthes* and sorghum at the end of the rainy season.

In ‘DMC maize // soybean’, high biomass inputs were achieved at least 1 year in 2 from the maize residue and the associated cover crop mulch. Soybean yields were higher and more regular (1680–2335 kg ha⁻¹), if still limited, likely because of the reduced level of fertiliser application in F1.

At KC-B, yields in ‘plough sesame / soybean’ varied widely (870–2020 kg ha⁻¹), but around a higher median than at KC-R, revealing the higher ‘fertility’ level at KC-B. Yields under ‘DMC cassava // soybean’ (1305–2225 kg ha⁻¹) and ‘DMC maize // soybean’ (1460–2300 kg ha⁻¹) showed small improvements.
At KC-R, yields of maize in ‘DMC maize // soybean’ were erratic (1795–7130 kg ha\textsuperscript{-1}) compared with those in the much steadier ‘DMC maize’ (4760–5660 kg ha\textsuperscript{-1}). In addition to the variations in the production of the cover crops sown in association with soybean, up to 2009, maize was associated with \textit{Brachiaria ruziziensis}, considered a better cover crop to precede soybean, and was thus prone to fierce competition (as in 2008). This problem appeared less acute with F2, where the more vigorous maize could control the \textit{Brachiaria} by rapid shading of the inter-row space. Confirmation of this effect in several demonstration plots led us to discard \textit{Brachiaria ruziziensis} as a cover crop species for smallholders in Cambodia.

At KC-B, maize yields also oscillated owing to variations in \textit{Stylosanthes} biomass inputs, more so in association with soybean (‘DMC maize // soybean’) than with cassava (‘MT maize // cassava’).

The cassava-based cropping systems at KC-B illustrate the capacity of the DATE approach to build up technical propositions in ‘real-time’. In 2009, all DMC-based systems showed reducing cassava yields, below those of the reference ‘plough cassava’.
So in 2010, the project participants decided to use row strip tillage by chisel plough (considered a ‘lesser evil’). In 2010 and 2011, yields were 15 530 kg ha\(^{-1}\) in ‘MT cassava’ and 14 960 kg ha\(^{-1}\) in ‘MT maize // cassava’ versus 12 310 kg ha\(^{-1}\) in ‘plough cassava’.

**Figure 4.** Yields (kg/ha of peeled, sun-dried tubers) of cassava at KC-B with F1 fertiliser.

The weight of peeled, sun-dried tubers harvested in January–February is about 45% of the fresh weight.

### 3.1.2. Demonstration plots

**Figure 5.** Yields of (a) soybean and (b) maize (kg/ha of grain at 14% moisture) under ‘DMC maize // soybean’ in the demonstration plots.

The crop performance in ‘DMC maize // soybean’ at the KC-R demonstration plots were similar to or even better than those on the similar soil at the KC-R matrix plots.

In Battambang, the system performed poorly owing to poor growth of *Stylosanthes guianensis* on the neutral–basic Mollisol. Alternatives were actively sought during 2010 and 2011: both rice-bean (*Vigna umbellata*) and pigeon pea produced large amounts of biomass when grown in association with maize, but the farmers unanimously rejected the former, which climbed up the maize stems before harvest.
The results of ‘MT cassava’ at KC-B2 and KC-B3 were similar to those at the KC-B matrix plots, notably around the time of the introduction of strip tillage in 2010. The lower performance at KC-B3 is linked to the extremely depleted soil at this site, which was chosen for its representativeness of most farmers’ plots in KC.

Strip tillage was also introduced at KC-R4, even though (in the absence of background results for the cassava-based system at KC-R) no clear physical limitations were observable at this time. The moderate to poor results of ‘DMC maize’ at Battambang 1 and 2 were due to the limited growth of *Stylosanthes* on the Mollisol. They reflect more the poor project management at KC-B1 than the cropping system itself.

The results of ‘MT maize // cassava’ at KC-B1 and KC-B2 were consistent with the performance at KC-B, notably the decreasing maize yields. Although this experimental design does not allow us to explain why, this point questions the capacity to maintain high productivity with limited mineral inputs. The less robust maize might reveal this trend before cassava.
3.2. On-farm cropping systems performances

As expected, the farmers started to adopt DMC-based cropping systems targeting the same production goals (to maximise profit) on a comparable calendar as for the main crops. Thus, in KC, they favoured ‘MT cassava’, some of them introducing maize + *Stylosanthes* in the rotation in 2010, as recommended by the project to improve biomass inputs. In Battambang, all farmers started to adopt ‘DMC maize’.

In KC, starting from severely degraded soil, MT with associated cover crops has triggered a rapid improvement in cassava yields, from 7.6 Mg ha\(^{-1}\) in 2009 to 11.1 Mg ha\(^{-1}\) in 2011. At the same time, control cassava yields decreased from 6.4 to 5.5 Mg ha\(^{-1}\).

In Battambang, the performance of the farmers’ ‘DMC maize’ has been impaired, as in the Battambang 1 and 2 demonstration plots, by the absence of significant biomass production by the cover crops (predominantly *Stylosanthes*) up to 2011.

The results confirm that no-till without a cover crops under tropical conditions performs poorly, increasing the difficulty of controlling weeds, notably *Euphorbia heterophylla*, *Sorghum halepense* and *Rottboellia cochinchinensis*. But the smallholders are also interested in the simplification of cropping and are aware of the fertility degradation under conventional tillage and clearly shown in the control plots.

**Figure 8.** Average yields of cassava (kg/ha of peeled, sun-dried tubers) and maize (kg/ha of grain at 14% moisture) in the farmers’ plots and control plots in KC.
4. Discussion

4.1. DMC cropping systems

This work highlights the effect of DMC on the restoration of the soil’s production capacity. For example, on KC-R2, soybean yields increased in 6 years from <500 to 2500 kg ha\(^{-1}\) and maize yields from 3000 to almost 7200 kg ha\(^{-1}\), with limited mineral fertiliser application (F1 fertilisers cost the equivalent of 350 kg of soybean grain and 800 kg of maize grain). Nevertheless, as the cropping systems have improved, along with the transfer and acquisition of knowhow by farmers, technicians and agronomists, the pace of restoration has slowed.

The efficiency of DMC appears to be linked first to the quantity of fresh organic matter inputs; in this regard, systems whose biomass inputs are threatened by climate variations show erratic recovery. Under Cambodian conditions, this is the case when the associated cover crop is sown at the beginning (with cassava) or at the end (with soybean) of the rainy season. Cassava and its associated cover crops have a 9- to 10-month growth cycle. Thus, fearing strong competition, initial recommendation was to sow cover crop after the full emergence of the cassava, leading to uncertainty in the cover crops development by possible poor germination (due to limited and scattered rainfalls of April and May) and rapid shading by the cassava.
Experience over several years with contrasting weather led to the decision to plant the cassava and *Stylosanthes* at the same time. This strategy allows the cover crop to establish in case of insufficient early rain (time remaining for complement sowing), although competition still occurs only on severely depleted soils. In this case, as observed in the pilot extension network, the cassava still produces more than in the plough-based system, while the large biomass of *Stylosanthes* boosts soil recovery. This DMC system shows resilience through its capacity to evolve on poor soil into a productive, income-generating ‘cassava-based fallow’.

In soybean, cover crops have been broadcast-sown at the end of September to early October, at the beginning of soybean defoliation, about a month before harvest. This timing, however, is prone to an early end to the rains. It could appear simple to then sow the soybean earlier, in June to early July, but this increases the risk of exposing its maturation to the important rains of September–October, impairing quality, especially in the absence of drying capacity. Another solution could be to sow soybean and *Stylosanthes* simultaneously, using a reduced row spacing to give earlier shading and the capacity to regulate competition by herbicide obviously requiring good technical mastery. Pending a skill upgrade, another solution is to reduce the frequency of soybean in the rotation (e.g. ‘MT cassava // maize // soybean’), which would also reduce the frequency of strip tillage before the cassava.

These developments hint that the progressive improvement of species diversity in DMC systems—still poor in Cambodia—follow increased biomass inputs. We can even consider that the primary function of increasing the diversity of cover crop species is to secure and strengthen the biomass inputs. Once this achieved, it will be possible to screen species for the introduction of specific functions.

### 4.2. DATE methodology

DATE relies on the dynamic testing and assessing of cropping systems and components in multiscale iterations. It leads to a rapid and continuous adjustment of the technologies with progressively improved technical and economic performance, along with a better fit to smallholders’ conditions.

As implemented here, the DATE approach provides a living model of the local references and an interactive and permanent display of the production systems in their agrarian context. This intimate contact with rural dynamics allows participants to anticipate future evolution and to craft improvements for the benefit of the different stakeholders.

The noticeable near-absence of distortions of the cropping systems’ performance in the scaling up and transfer offers maybe the best indicator of the methodology’s efficiency. The efficiency is due mainly to the embedding of all stages in real farm environments and the continuous attention to the practical training and technical mastery of all participants.

Nevertheless, some important limits must be acknowledged.
First, the ‘instantaneous’ assessment of a tested proposition must be cautiously considered, taking into account the slow transformation of the agroecosystem triggered by DMC. For example, the ‘urgent’ introduction of strip tillage before cassava planting to reverse downward yield trends has been necessary, but it would not have been necessary if the earlier introduction of DMC had restored the soil structure, or if a cassava crop had been inserted at a 3- or 4-year frequency in association with a cover crop species chosen for strong root system development (e.g. *Eleusine coracana*, *Crotalaria*). In the meantime, the consequences of this tillage, especially if practised every year as in ‘MT cassava’, on the soil organic carbon balance remains an open question, if we keep in mind the -sometimes forgotten- evidence that improvement of performance doesn’t necessary pair with sustainability.

These limits must be addressed by a medium- to long-term assessment of the technologies developed. For the complete validation of sustainability, the agronomic and environmental impacts on agroecosystems need to be measured, in addition to their technical and economic performance. This necessary work has to be implemented, as soon as technologies are designed and in adoption–diffusion process, through parallel experiments. This characterisation will also reveal the processes setting the technical efficiency. One such process -the pathway of soil organic carbon restoration under DMC- has begun to be explained (Tivet 2013). In turn, this explanation lays the necessity to combine at least 2 of the 3 CA principles (minimum soil disturbance, permanent soil cover) in inducing a positive C balance in soils under tropical conditions.

5. Conclusion

This work gives a clear illustration of the agro-technical and economic (Chabierski et al. 2012) improvements brought by an initial set of relatively simple DMC cropping systems. This set has been created through the implementation of the DATE approach, starting from the local tillage-based practices (using the same production goals, a similar calendar and similar labour organisation) and the important set of DMC technology references developed in tropical regions of Brazil (Séguy et al. 2008, 2009).

The work shows how the DMC principles, which support the essence of CA, frame and fix the limits of the adaptation process to the biophysical and socioeconomic environment presented. This process must respect the 3 CA principles, not as a ‘package’ but as the basis of its internal cohesion, on pain of creating innovative but unsustainable cropping systems.

If CA is considered a major invention, opening the way to sustainable upland rainfed agriculture under tropical conditions with real opportunities for poverty alleviation and the provision of collective services, then these limits in turn define the contours of needed ‘environment adaptation’ for technology diffusion among farmers. Such ‘environmental enabling’ should be fully associated with the development of CA into a holistic approach, involving socioeconomic engineering.


http://agroecologie.cirad.fr/content/download/7200/35181/file/1212319668.pdf;
http://agroecologie.cirad.fr/content/download/7833/39824/file/Symphonie_inachevee_10_Mo_A.pdf;
http://agroecologie.cirad.fr/content/download/7834/39831/file/Symphonie_inachevee_10_Mo_B.pdf;

Séguy, L., Bouzinac S., Brazilian partners. 2009. La saga SEBOTA. Les riz polyaptitudes SEBOTAS (SBT) créés pour et dans des systèmes de culture durables en semis direct sur couvertures végétales au service de rizicultures alternatives performantes, diversifiées, propres et à faible coût. 388 p. In CIRAD web library:

http://agroecologie.cirad.fr/content/download/7726/39229/file/LA_SAGA_SEBOTA_CHAPITRE_I_ET_II.pdf
http://agroecologie.cirad.fr/content/download/7733/39276/file/LA_SAGA_SEBOTA_CHAPITRE3bis.pdf

Adaptive participatory research to develop innovations for sustainable intensification of maize-based farming systems in the northern uplands of Vietnam

Pham Thi Sen*1, Le Huu Huan1, Do Sy An1, Dang Van Cong3, Trinh Van Nam1, Oleg Nicetic2, Elske van de Fliert2, Le Quoc Doanh1

1 Northern Mountainous Agriculture and Forestry Science Institute, Phu Ho, Phu Tho, Vietnam
2 Centre for Communication and Social Change, School for Journalism and Communication, The University of Queensland, Brisbane, Qld 4072, Australia.
3 Tay Bac University, Son La City, Son La, Vietnam

*Corresponding author: Phamthisenprc@yahoo.com

In the northern mountainous region (NMR) of Vietnam, maize (Zea mays) is one of the most important crops. The region’s total maize area exceeded 460 000 ha (>40% of the total) in 2010, producing over 1.5 million t of grain (>31% of the total production of maize in the country) (General Statistics Office, 2011). Increasing demands for maize by the feed industry and increasing cash requirements of local rural households have resulted in continuous expansion of the maize area and intensification of production. This has pushed maize cultivation onto degraded sloping lands. Maize crops in the NMR have already climbed up and often reached the tops of slopes with an inclination of over 25°, despite government efforts to restrict the cultivation of annual crops to flatter lands at lower elevations. This has created the need for the on-farm application of technical innovations to support sustainable intensification of maize production and for the restoration of degraded sloping lands. Significant attempts have been made to develop sustainable soil management techniques, including mulching, mini-terracing and intercropping. These techniques were effective at soil protection and to a certain extent increased the profitability of maize crops (Le at al., 2003; Le and Ha, 2008). Nevertheless, although they have been available for many years, they have not been applied on a large scale, and some tens to hundreds of tonnes of soil continue to be washed away from each hectare of sloping land in the NMR every year (Kirchhof et al., 2012). One of the main reasons for the low adoption of erosion management is the incompatibility of the recommended techniques with the socio-economic characteristics of smallholder farmers in the NMR (Nicetic et al., 2012).

Aiming to design techniques of mulching, mini-terracing and intercropping that smallholder maize farmers in the NMR can successfully adopt, in collaboration with local farmers, we began research in 2009 in six locations with different land, climatic and socioeconomic conditions: research sites were established in six communes in Son La and Lai Chau provinces.
The experiments were planned, established, conducted and evaluated in collaboration with farmers on their own farms. Farmers carried out most of the field work, and took part in regular monitoring and evaluation of the experiments. At harvest, the farmer-researchers and other farmers offered their observations and opinions in community feedback meetings.

An economic analysis of each technique was done with the farmer-researchers and was presented at the meetings. Discussion of both positive and negative impacts of the techniques allowed the techniques to be modified. The modified techniques were then tested in the following season, and the monitoring and evaluation was repeated. Two to four cycles of this participatory adaptive research resulted in soil erosion management techniques that are applicable to the prevailing socioeconomic and environmental conditions at each site.

It has become clear after 3 years that location-specific adaptation is necessary to make the techniques attractive to farmers, and that “small” modifications can have a deciding role in enhancing adoption. A good example is provided by the development of suitable soil cover techniques. The previous recommendation of 5–7 t/ha of plant residues appeared to be too much to allow maize seeds to germinate normally. Our observations showed that half of this amount still had good erosion prevention effects while improving seed germination. In addition, field-based trials showed that, depending on the time interval between the harvest of one crop and the sowing of the next, different treatments of mulching materials might be required. The main concern that became evident, and is still a key question, is how farmers can collect or produce enough mulching materials. Currently, free grazing during autumn and winter limits the availability of maize crop residues to be used for mulching in the next crop. As a result, relay crops or intercrops need to be grown for biomass production, and fields have to be fenced or guarded to keep stock out. But in the NMR, where both the rate and the density of poverty remain the highest within Vietnam, plants with no immediate economic value would not be accepted, and there is no perception among farmers that soil cover provides value. Indeed, different intercrops were initially accepted not because of their soil protection value, but for their economic or use values. For example, Guatemala grass (*Tripsacum laxum*) was accepted in one location where buffaloes were raised; soybean in another, where farmers had the knowledge and skills to manage intercropped soybean for good economic return; and rice bean (*Vigna umbellata*) in yet another, where it was traditionally cultivated with maize for human consumption. The methods for planting intercrops also differed from location to location, with variations in row distance and intercrop density.

Similarly, variations in tillage methods were required. The appropriateness of land preparation and sowing methods, given the availability of labour, draft animals, agricultural mechanisation and soil cultivation tools, primarily determined their adoptability. In the NMR, where labour is short at critical times and there are no readily available tools for direct sowing, minimum tillage, whereby furrows are made either by cultivator pulled by buffalo or manually by hoes, is preferred to zero tillage.
Out of various options for land preparation and seed sowing recommended by our project, farmers in different locations have made different choices depending on their soil structure, land area, land slope, and labour and tool availability. For instance, farmers in one location with small plots on rocky soils chose to use hoes to make furrows or holes for fertilisers and seeds, while on larger areas they used buffaloes to make furrows.

In another location, where the soil was very poor and hard, in the first year farmers decided to plough and then apply mulch.

In summary, the specific ethnic, socioeconomic, land, climatic and topographical conditions of the NMR militate against the adoption of a conventional conservation agriculture approach of no soil disturbance and permanent soil cover. Through adaptive participatory research, our project developed adaptable soil management techniques based on the principles of mulching, minimum tillage, mini-terracing and intercropping that can be widely applied by smallholder maize farmers in the NMR.

**Keywords**

Sustainable agriculture, adaptive research, erosion control, north-western Vietnam

**References**


Complementing traditional crop cultivation with agro-ecological interventions: supporting farmer innovations in eastern India

Vidhya Das* and Achyut Das²

1 Programme Advisor, Agragamee, PO Kashipur, Dist. Rayagada, Odisha 765015, India.
2 Director, Agragamee, PO Kashipur, Dist. Rayagada, Odisha 765015, India.

*Corresponding author: vidhyadas@agragamee.org

Eastern India is home to some of the poorest indigenous communities on Earth. Various national and international funding agencies have provided development programs, yet despite substantial commitment and sincere effort, the communities remain poor.

Traditional cultivation in this region has sustained an agricultural biodiversity of several land-races of millets, pulses, upland and lowland rice, and oilseeds. These crops supplement food gathered from the forests, and provide surpluses for sale. However, much of the communities’ livelihood is being destroyed owing to derecognition of tribal tenurial rights, denial of access to forests, and industrialisation and modernisation, which have led to large-scale evictions and land alienation.

In addition to aid programs, horticulture and agriculture extension programs have provided support for crop diversification, including growing coffee, black pepper, eucalyptus and bamboo for biofuel, tomatoes, maize, cotton, soybean, sunflower and spices. However, these enterprises have benefited private business but not local farmers.

Seeking to improve tribal livelihoods and agricultural systems, we began trials. After having limited success with permaculture, biodynamic farming and composting, we tried the “natural farming” philosophy of Masanobu Fukuoka, a more eco-friendly form of conservation agriculture. Our successes encouraged dialogue with tribal farmers, who showed good understanding of these ideas, and came up with local efforts, which 25 farmers volunteered to try.

In the first season, we encouraged farmers to fence in their plots. Local pigeon pea (Cajanus cajan) was intercropped with rice bean (Vigna umbellata), a traditional practice in this region. Unfortunately, the rice bean crop perished for want of rainfall, and the pigeon pea suffered losses to pests. Ten farmers lost hope and did not mend their fences: the cattle grazed, and the farmers had to start anew the next season. However, 15 farmers guarded their fences well: the grass grew thick, and the pigeon pea plants survived the dry weather.
In the second season, the farmers cut the grass down as mulch around the pigeon pea, and dribbled in cowpea (*Vigna unguiculata*) seeds. The cowpea gave an average yield, which most of the farmers ate as greens. The pigeon pea, however, yielded a bumper crop, surprising everyone, as the crop failed in the rest of the region owing to unseasonal rains.

The successes followed innovations. The first is the fencing of the land. Boulders strewn throughout the fields made good materials. Where there were not enough, farmers planted non-browsable trees close together that they could then crop for firewood at ~3 m height. Other farmers planted non-browsable fast growing plants in multiple rows to give strength and thickness.

In Badabagri village, farmer DJ mulched his pigeon pea plot with the previous years’ residue from the niger (*Guizotia abyssinica*) harvest. The niger also sprouted and grew much more vigorously than in neighbouring fields, where it had been deliberately broadcast. Thus, DJ gained a yield of niger, as well as pigeon pea, with very little effort.

The most innovative efforts were those of farmer SSM, who had acquired the title to 1 ha of degraded stony upland with slopes ranging from 5° to 10°. Normally, this land could be cultivated only in 5- to 7-year cycles of shifting cultivation. SSM was eager to try out natural farming. He fenced it in and intercropped maize between pigeon pea and rice bean on 0.25 ha on the downhill side. Around the borders he broadcast millet, and mulched the ground with straw and grass. Even though the pigeon pea and rice bean did poorly, SSM harvested 50 kg of maize and 20 kg of millet in the first year.

In the second year, he broadcast a mix of finger millet (*Eleusine coracana*), pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*) and kosala (possibly *Panicum sumatrense*) between the standing pigeon pea, and then dribbled cowpea in between. He covered this with a mulch of grass and straw. He harvested 150 kg of millet and 100 kg of pigeon pea, a bumper crop. Cattle knocked down the stone wall, so SSM grew three rows of non-browsable hedge plants outside the fence.

In the third year, on land that would previously have had to be left fallow, SSM is again growing millet and the yields are increasing.

SSM’s efforts have encouraged women to come together to reclaim common lands with a similar approach. In addition, farmer GM has tried the approach on his rice field and has got twice the yield of other farmers.

The process needs much more support for scaling up and establishment as a viable alternative. An integrated ecosystem approach needs to be developed to help tribal communities meet food and livelihood needs. Government and international funding must link up with research institutes and civil society organisations for more innovative programs towards this goal.
Keywords

Tribal farming systems, rejuvenation, rainfed uplands, natural farming, agricultural biodiversity

Bibliography

‘Oasis sofa’: application of conservation agriculture in urban vegetable production

Manuel Reyes*1, Don Immanuel Edralin1, Lyda Hok1 and Kieu Ngoc Le1

1 Biological Engineering, North Carolina Agricultural and Technical State University, Greensboro, NC 27411, USA

*Corresponding author: reyes@ag.ncat.edu

Most lawns in the USA are heavily dependent on fossil fuel for maintenance, and require fertilisers and pesticides that pollute rivers and lakes (NOAA 2008). Millions of families in the USA live in ‘home deserts’ with no access to fresh nutritious food (NewsOne 2011; The Economist 2011). Growing vegetables at home using conservation agriculture (CA) practices of minimum soil disturbance, continuous mulching and diverse cropping can bring nutritious foods to many households. Households can convert part of their lawn into a vegetable garden and grow artificial-chemical-free food. This can bring environmental benefits by reducing the movement of fertilisers and pesticides from lawns into waterways, including drinking water sources, and reducing the use of fossil fuel for mowing lawns.

‘Oasis sofas’ are sofa-sized (~1.8 m x 0.9 m) raised beds planted with vegetables following the concepts of CA. The name refers to the capacity of an oasis to supply healthy food to home deserts and to the ‘couch potatoes’ the practice aims to discourage through working on the oasis sofas.

We constructed 32 oasis sofas to trial vegetable production in urban homes. Eight beds each received 1 of the following 4 treatments: continuous vegetables all year with soil tilled; continuous vegetables all year with no tillage; cover crop in autumn, winter and early spring, and vegetables in mid spring and summer; and cover crop in mid spring and summer, and vegetables in autumn, winter and early spring. All beds were irrigated with rainwater stored in a tank and fertilised with organic fertiliser. No pesticides were applied. Soil quality, biomass and crop yield were measured for two cropping seasons. Autumn-transplanted unfertilised broccoli, collard greens, kale and lettuce yielded the equivalent of 2.5, 1.5, 1.0 and 1.4 Mg/ha, respectively. As this was the first crop, no treatment differences were seen. The yields of late-spring-planted tomatoes, eggplant and okra will be reported after the September 2012 harvest.

As far as we know this is the first experiment anywhere of the potential of CA for vegetable production in urban backyards. Our students and staff aim to develop a technology that can encourage homeowners to build their own oasis sofas. Similar studies have also been started in 6 schools.
Part of the capital and hired labour used to maintain lawns can be diverted to oasis sofas, bringing benefits of nutritious fresh food at no extra cost. Oasis sofas enhance access to home-grown healthy food and reconnect people to their food supply and to healthy eating.

**Keywords**

Conservation agriculture, urban stormwater, organic vegetable

**References**


Crop associations and successions in conservation agriculture: implications for system design, training and extension

Olivier Husson*1, André Chabanne1
1 CIRAD, UPR SIA, F-34398 Montpellier, France

*Corresponding author : olivier.husson@cirad.fr

In intensive agriculture, the 4 main functions required for agricultural production -maintenance of soil structure, weed control, pest control, and supply and uptake of water and nutrients- are directly assured by simple crop management sequences, especially land preparation and chemical inputs. In contrast, direct-seeding, mulch-based cropping systems aim at assuring these functions indirectly (Fig. 1), through the production of diversified crops and cover plants in associations and successions (first principle of conservation agriculture [CA]). Biomass production and minimal soil disturbance (second principle) allow the maintenance of a permanent soil cover (third principle).

The 4 functions of production are realised in multiple interactions by (Séguy et al. 2012):
• the plants -contributing to weed control, pest control, soil structure improvement by root systems, and nutrient extraction and recycling
• the litter -contributing to weed control and soil protection
• the intense biological activity -involved in pest control, soil aggregation, humification, and the mineralisation and solubilisation of nutrients
• soil organic matter -involved in soil aggregation and plant nutrition through mineralisation.

Thus, plants are the main ‘tools’ of CA, which relies on the return of large amounts of biomass to the soil. The quality of the biomass (related to plant species) determines the type of function. The quantity of the biomass controls the intensity at which a function is performed (Séguy et al. 2006; Scopel et al. 2012).

This paradigm has strong implications for system design, training and extension. The crop management sequences are intended to avoid competition between crops and cover plants, and to maximise biomass production. CA is knowledge intensive and does not propose a simple technological package.

Direct-seeding mulch-based cropping systems have to be locally adapted, which requires specific training of researchers, extension staff, farmers and other stakeholders.
Keywords

Crop succession, adaptation

References


Figure 1. Principles of, agents involved in and functions assured in CA.
Save and grow: minimum-tillage IPM in rice-based potato cropping in Vietnam

Ngo Tien Dung1, Johannes W.H. Ketelaar2, Alma Linda M. Abubakar*

1 Plant Protection Sub Department, Ministry of Agriculture and Rural Development, Vietnam
2 FAO Asia Regional IPM/Pesticide Risk Reduction Programme, FAO Regional Office for Asia and Pacific, Bangkok, Thailand

*Corresponding author: AlmaLinda.Abubakar@fao.org

This study had 3 aims: to increase the knowledge and profits of farmers through the growing of minimum-tillage potato with rice straw mulch; to promote climate-smart agriculture; and to reduce environmental pollution caused by burning rice straw.

We selected two villages (Thai Giang and Vu An) in Thai Binh province, Vietnam, for a study of the potential for production innovation and of pesticide use patterns in potato production in rice-based cropping systems. The Plant Protection Sub Department (PPSD) of the Ministry of Agriculture and Rural Development facilitated a dialogue with commune and cooperative leaders and IPM Farmer Field School (FFS) graduate farmers on the design of the study. The IPM FFS graduates had learned skills in designing and implementing field studies to give them a deeper understanding of the factors that affect plant growth and to find solutions to problems in crop production and protection.

In Thai Binh, potato productivity had been low, and areas planted to the crop had declined owing to a lack of good-quality seed potatoes and to high labour costs, especially as younger rural workers move to the cities. This labour migration left women—especially the elderly—to run the farms. Since conventional potato production is labour intensive, many families had shifted to planting other crops. However, potato is an important winter rotation and food crop and provides a stable income for smallholders.

Initially funded by the FAO Regional IPM Programme under the Swedish-supported Pesticide Risk Reduction Programme and later supported by Oxfam America–Vietnam, the study was facilitated by IPM trainers from the Thai Binh PPSD, and involved 25 IPM FFS graduates. The trial compared minimum tillage and IPM (T1) with farmers' practice (T2) on 1 ha each during 3 winter production seasons (2009–2011). T1 received 1900 kg muck, 270 kg N, 420 kg phosphate and 224 kg K. T2 received 1900 kg muck, 300 kg N, 420 kg phosphate and 195 kg K (Thai Binh PPSD 2012).

In T1, after the rice was harvested, the field was not ploughed. Instead, furrows 30 cm wide and 25 cm deep were created for drainage, resulting in raised beds about 50–70 cm wide.
Fertilisers were applied and covered with a thin layer of soil to protect the seed potatoes. The entire beds were then covered with rice straw (7–10 cm thick) from the recent harvest. Fertiliser and rice straw were again added at 20 and 35 days after planting. Rice straw from 4 ha covered 1 ha of potato. During soil preparation, the soil moisture content was about 70% to 80%, and the furrows were flood-irrigated 3, 20, 35 and 50 days after planting.

In T2, following the local practice, the rice fields were ploughed after harvesting, and seed potatoes were planted.

Once a week, observations of plant growth and development, pests, diseases, natural enemies, productivity during tuber initiation and bulking to maturation were recorded.

Plants in T1 sprouted earlier (8–12 days after planting) and produced more sprouts (2.40–2.60) than plants in T2 (10–12 days, 2.30–2.50 sprouts). Plants were hardier and taller in T1 (65–70 cm) than in T2 (60–65 cm). A quarter of the plants in T2 showed lodging at the end of the season. Pest problems were minimal, but at the start of the season mancozeb was applied twice in T2 and once in T1 to control Phytophthora infestans. At 70 days after planting, *Pseudomonas solanacearum* was present in 2.5% of plants in T1 and 3.5% in T2. *Fusarium oxysporum* was present in 2.4% of plants in T1 and 4.4% in T2 (P < 0.05).

In each year, the yields of minimum-tillage potato were higher than that of conventional practice. In 2011, minimum-tillage IPM saved a total of about 193 person days, or about VND 26 300 000/ha. Savings came mainly from a reduction of labour costs for land preparation, planting and harvesting. Minimum-tillage improved profits by USD 1690/ha in 2009, USD 2070 in 2010 and USD 1985 in 2011.

Plants in T1 were taller and more sturdy and had less disease incidence. Minimum-tillage improved yields by 2.2–2.4 Mg/ha each year, or about 10%. Labour costs were reduced by 46%, mainly because there was no need to dig, especially at planting and harvesting, and because the mulching reduced the need for irrigation (Table 1). Minimum-tillage IPM increased the annual profit by 60% to 73%.

### Table 1. Labour costs (VND) in minimum tillage and farmers' practice potato production.

<table>
<thead>
<tr>
<th>Labour costs components</th>
<th>Minimum tillage (T1)</th>
<th>Farmer's practice (T2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land preparation</td>
<td>2 700 000</td>
<td>8 100 000</td>
</tr>
<tr>
<td>Planting</td>
<td>5 400 000</td>
<td>8 300 000</td>
</tr>
<tr>
<td>Collection of rice straw</td>
<td>2 800 000</td>
<td>0</td>
</tr>
<tr>
<td>Taking care of fields</td>
<td>10 800 000</td>
<td>18 900 000</td>
</tr>
<tr>
<td>Spraying pesticides</td>
<td>2 800 000</td>
<td>5 600 000</td>
</tr>
<tr>
<td>Harvesting</td>
<td>5 400 000</td>
<td>8 300 000</td>
</tr>
<tr>
<td>Total costs (/ha)</td>
<td>22 900 000</td>
<td>49 200 000</td>
</tr>
<tr>
<td>Person days</td>
<td>168</td>
<td>361</td>
</tr>
</tbody>
</table>
More importantly, the use of rice straw for mulching puts nutrients back in the soil and reduces the emissions of greenhouse gases associated with the conventional practice of burning straw.

Mulch provides an important habitat for natural enemies, which are vital for pest population regulation. In addition, mulching can reduce water use for irrigation from 5000 m³ to 900 m³/ha (FAO 2012).

On 24 August 2011, the Ministry of Agriculture and Rural Development recognised minimum-tillage IPM as a promising model and issued Directive 1380/BVTV-TV for all potato-producing provinces in the country to apply the practice beginning in spring of 2012 (Nguyen 2011).

**Keywords**

Farmer field school, mulching, integrated pest management

**References**


Community seed system as a mechanism for delivery of conservation agriculture in the marginal uplands of the Arakan Valley, Cotabato, the Philippines

D. Manzanilla*1, R. Fe Hondrade2, E. Hondrade2, C. Vera Cruz1, K. Garrett3, C.C. Mundt4, A. Tobias1, L. A. Ocampo1, D. Johnson1

1 International Rice Research Institute, Manila, Philippines
2 University of Southern Mindanao, North Cotabato, Philippines
3 Kansas State University, Manhattan, KS 66506-5502, USA
4 Oregon State University, Corvallis, OR 97331-2902, USA

*Corresponding author: d.manzanilla@irri.org

In the marginal uplands of the Arakan Valley (Cotabato, the Philippines) and similar environments, farmers lack good-quality seeds, have little or no access to improved cultivars, face soil degradation and low fertility, lack access to technologies and information, and lose production and income to frequent drought and other crop stresses. Good-quality seeds of well adapted cultivars are essential to improving farm productivity, but farmers have limited access and rely on poor-quality seeds of low-yielding cultivars.

In this challenging environment, we have been developing a mechanism for the delivery of conservation agriculture (CA) technologies, such as the cultivation of crops that add to income and system resilience, improved rice cultivars and seed health management, among smallholders. An innovative model of seed supply and information sharing is being supported through the University of Southern Mindanao and the Consortium for Unfavorable Rice Environments of IRRI. This model is now the basis for establishing community-based seed systems (CBSSs) in many parts of the Philippines and other Asian countries, through which trained farmers exchange good-quality seeds and effective management options. The mechanism supports CA through the integration of new cultivars with traditional ones, management options for crops with less inputs, and better resilience, in a delivery system accepted by communities. It also supports multiple objectives of sustainable land management, biodiversity conservation and meeting the socioeconomic needs of the farmers through seed and food security.

The mechanism combines the production of premium traditional aromatic rice (‘Dinorado’) and new high-yielding inbred cultivars, such as ‘NSIC RC9’ and ‘UPL Ri5’, selected through participatory approaches, to improve income. Other crop management practices introduced follow the principles of CA, including permanent soil cover, crop rotation and the reduction or elimination of chemical use.
Further, to diversify income sources and to improve enterprise resilience, farmers diversify their crops, particularly by growing rice, mung bean and young rubber trees.

This paper assesses the mechanism as a means for the delivery of CA, seeds and innovations that farmers want and its contribution to sustainable livelihood. Specifically, it documents the model and its components, including CA technologies; assesses the model’s impacts on seed security, rice productivity and livelihoods in the upland ecosystem of the Arakan Valley; and assesses the effects of crop diversification and system constraints (e.g. disease severity and weed biomass).

A survey of 144 respondents showed that education, access to rice cultivars, access to extension services and labour availability were significant positive influences on the adoption of CBSS technologies. The average yield of Dinorado increased from only 0.9 Mg/ha in 2003, before the CBSS was established, to 1.7 Mg/ha in 2010. Members of the local seed bank had the highest mean income from rice (USD 1252 = PHP 54 701 per ha). The “hungry months” period was reduced from 6–8 months to 3 months (mainly April to June). Not only did the CBSS provide access to preferred cultivars, but the use of good-quality seeds reduced the sowing rate, increased the crop emergence rate (>70%), reduced replanting labour, and gave a more uniform plant stand and more vigorous early crop growth. Yields of Dinorado, UPL Ri5 and mung bean were significantly higher in mixtures or by intercropping than in monoculture, and some crops had lower weed biomass. These combinations were the most efficient in terms of grain yield.

Factors contributing to farmers’ uptake of CBSS technologies were access to good-quality seeds, participation in varietal trials, access to training, available resources, contact with extension workers, favourable weather and farmers’ preference for upland rice. CBSS activities could be extended in a broader approach to sustainable community development. There is a need for policy initiatives to promote the establishment of CBSSs, to foster seed exchange, and to train farmers in the benefits of CA. Mechanisms for sharing knowledge among initiatives are necessary. Models of community seed banks should be documented to support policy initiatives in building viable CBSSs in uplands and stress-prone rice communities and in introducing CA technologies. Lastly, it is important to show farmers how applying CA principles can contribute to income.

**Keywords**

Seed security, CA, crop diversification, seed bank
Conservation Agriculture and Sustainable Upland Livelihoods

Community-based resource assessment and management planning for the rice terraces of Hungduan, Ifugao, Philippines

Margaret M. Calderon*, Nathaniel C. Bantayan1, Josefina T. Dizon2, Asa Jose U. Sajise3, Analyn L. Codilan1 and Myranel G. Salvador1

1 Institute of Renewable Natural Resources, College of Forestry and Natural Resources, University of the Philippines Los Baños, College, Laguna, Philippines. Fax: +63 49 536 2557

2 Community Innovations Studies Center, College of Public Affairs and Development, University of the Philippines Los Baños, College, Laguna, Philippines

3 Department of Economics, College of Economics and Management, University of the Philippines Los Baños, College, Laguna, Philippines

*Corresponding author: bargecal@yahoo.com

The rice terraces in the municipality of Hungduan in the Philippine province of Ifugao, together with those in three other municipalities, were inscribed on the UNESCO World Heritage List in 1995 under the category of organically evolved landscapes. In 2001, the terraces were transferred to the World Heritage in Danger List, mainly because of terrace abandonment. The reasons for abandonment include low rice productivity, emigration, overcutting of woodlots, erosion and landslides, problems with irrigation, and the presence of pests such as golden snails and giant earthworms. The Philippine government intervened to reverse the deterioration, and succeeded in having the terraces removed from the World Heritage in Danger List in 2012.

However, threats to the terraces remain, due to both socioeconomic and biophysical factors, including climate change. Changing rainfall patterns have altered water availability. Studies established the Ifugao farmers’ need for support to sustain rice terrace farming, and a strong willingness to pay for the ecosystem services that the terraces provide. However, there are no realistic estimates of the extent of damage and the cost of rehabilitation at the farm level, on which payments can be based.

This paper discusses the results of a study designed to build the capacity of the farmers of Hungduan in community-based resource and damage assessment and management plan preparation. The study included site selection, capacity building of farmer groups for community-based management planning, and process documentation.

Project sites were selected on the basis of the communities’ willingness to participate, accessibility (for efficient monitoring), area of terrace–woodlot clusters and extent of damage.
With assistance from the Ifugao Cultural Heritage Office and the local government of Hungduan, we identified four subcatchments from which the farmer-participants were drawn. This approach departed from the usual practice of using political units such as barangays¹ in management planning.

To build the capacity of farmer groups, we conducted three training workshops on resource and damage assessment methods, community mapping and management plan preparation.

In the first workshop, the farmers were asked to locate their communal forests, trails and terraces on GIS-based maps, and indicate which terraces were damaged. The use of GPS, survey instruments, and grid-based assessment in generating data was demonstrated. The farmers then used these tools in the community-based resource assessment. The data gathered were used in the preparation of 3D maps showing land use.

With initial guidance from us in identifying and locating natural landmarks and boundaries, the farmers located barangays and sitios, terraces, woodlots and other landmarks on the maps. They were also asked to indicate whether the terraces were damaged or abandoned. The data from the 3D models were then transformed into GIS maps, which were used to provide estimates of location and area.

Through the project, the farmers learned several resource assessment techniques. They also used their indigenous knowledge in the identification of plant and animal species; in the identification of damaged or abandoned terraces; in defining the extent, ownership and location of terraces and woodlots; in delineating the boundaries of sitios and barangays on the ground; and in the use of natural landmarks and boundaries in locating properties, sitios and barangays. The 3D maps allowed them to better visualize their own landscape and accurately locate the different land uses on the map.

The total areas of rice terraces in the four subcatchments were estimated to be 623, 631, 1171 and 637 ha, while the proportions of damaged terraces ranged from 13% to 20%. Few terraces were abandoned.

The farmers at the workshops produced management plans detailing the available resources, strategies and achievable recommendations for the sustainable use of their terraces. Some farmers did not readily accept the use of the catchment as a management unit, perhaps because of their familiarity with political boundaries and the use of political units as management units.

Practical indigenous knowledge can be complemented with research techniques and tools to generate reliable information needed in the development of management plans for the conservation and protection of natural resources.

¹ A barangay is the smallest political unit in the Philippines, which can be further subdivided into sitios.
Bibliography


Bantayan NC. 2006. GIS in the Philippines – Principles and applications in forestry and natural resources. Los Banos: PARRFI and AKECU-AKECOP.


Evaluation of a plant-fibre-based stormwater filter for improving groundwater recharge quality

Manoj P. Samuel*¹, S. Senthilvel² and D. Tamilmani²

¹National Academy of Agricultural Research Management, Rajendranagar, Hyderabad 500 030, India. Tel: +91 91 7794 3425; Fax: +91 40 2458 1453
²Department of Soil and Water Conservation, Tamil Nadu Agricultural University, Coimbatore 641 003, India

*Corresponding author: manojpsamuel@gmail.com

As surface water sources fail to meet the rising demand for water supply in both urban and rural areas, groundwater reserves are being tapped and overexploited, resulting in a decline in groundwater levels and a deterioration in groundwater quality. In this context, we tested filters designed to improve the quality of stormwater before it is diverted to deep aquifers.

We designed a dual-flow stormwater filter and built a laboratory-scale model to test its hydraulic efficiency and pollutant removal efficiency. Influent stormwater first flows laterally through concentric bands of planted grass and plant fibres. The water then flows vertically through deep layers of pebbles and sand, before it finally recharges an aquifer. Three grass species were tested: Typha angustifolia (bulrush), Chrysopogon zizanioides (vetiver) and Stenotaphrum secundatum (St Augustine grass). Six plant fibres were tested for their capacity to adsorb nitrate; the adsorption capacity decreased in the order of coir > oil palm > sisal > hemp > jute > banana. Therefore, coconut (Cocos nucifera) fibre (coir) was selected.

Semi-synthetic stormwater that contained sediment and pollutants with characteristics typical of stormwater runoff was prepared in a 100-L tank by adding sieved silt (300 µm), sand and fertilizer (N, K₂O, P₂O₅) to well water. The hydraulic efficiency of the filter increased with flow rate when the flow rate was <0.08 L s⁻¹, but the permeability decreased above 0.08 L s⁻¹. The most effective filter medium comprised plants, fibre, pebbles and sand in the ratio of 2:1:2:1, followed by 1:1:2:1. The filter retained 52% (range 39%–61%) of water on average.

The filter removed 81.6% of K⁺ and 77.6% of Na⁺. Its efficiency at normalising pH and reducing electrical conductivity was high. The removal of Ca²⁺ was moderate, while the removal of Mg²⁺ was very low. In fact, C. zizanioides increased Mg²⁺. A substantial increase in the iron content in the effluent was due to the high iron content of the local soil that was used.

Typha angustifolia was the most effective live filter at removing chemicals, but S. secundatum was the most effective at reducing sediment load, followed by C. zizanioides.
The average sediment load reduction was only 23.4%, owing to the loose soil in the outer ring. The rate of removal increased after the plants were fully established.

We calculated a “universal performance index” as the weighted average of the hydraulic efficiency and the quality improvement efficiency. Analysis of variance showed that *T. angustifolia* performed best, followed by *C. zizanioides*. The best filter performance came from plants, fibre, pebbles and sand in the ratio of 1:1:1:2. Field evaluation of the best filter combination gave the same results.

Calculations of internal rate of return, net present value and benefit–cost ratio based on estimated annual costs and returns showed that the filtration system was favourable to farmers and affordable. The cost of filtration was as little as 2¢ per m³ of stormwater. The filtration system is a low-cost technology requiring low initial expenditure, no energy input, no maintenance and no external support.

**Keywords**

Recharge filter, vegetative medium, bio-fibre, pollutant removal efficiency, hydraulic efficiency, economic analysis

**Bibliography**


Institutional and policy options for improving the economic value of grassland in the mountainous regions of Vietnam: a case study in Son La Province

G. Duteurtre*1, Pham Thi Hanh Tho2, Trinh Van Tuan2, Stephen Ives3

1 CIRAD UMR SELMET, Ha Noi, Vietnam
2 Centre for Agrarian Systems Research and Development, Hanoi, Vietnam
3 Institute of Agricultural Research, University of Tasmania, Hobart, Tasmania, Australia

*Corresponding author: duteurtre@cirad.fr

Natural pastures are an important component of agricultural production systems in northern Vietnam. They provide the bulk of the feed resources used for cattle, goats and pigs raised under both total and partial grazing systems. They also provide complementary resources for animals raised under the cut-and-carry feed systems that prevail in certain areas. However, they are not formally recognised as grazing land by local authorities. They are either registered as forest lands or located on the fringes of agricultural land and public roads. We evaluated how local stakeholders consider natural grazing lands and what institutions are mobilised for their management. Our hypothesis was that the contribution of natural grazing lands to improving the economic value of beef cattle production relies on both technical and institutional innovations.

Our work builds on the existing literature on forest and agricultural land in the highlands of Vietnam, which emphasises the role of the local institutional framework. Until now, however, very few scientific contributions have shown the role of local institutions in the development of extensive cattle production there. Our study aimed at a better understanding of the roles of land tenure, credit, producers’ organisations, contractual relationships with traders and extension programs in the development of commercial beef cattle production. It highlights the need to promote collective action among livestock keepers in order to better balance the uses of forest lands for environmental conservation, forestry plantations, slash-and-burn agriculture and livestock production.

Our approach is based on the institutional economics literature that underlines the importance of understanding the local social context and historical transformations. We define an institution as ‘a collective action in control, liberation and expansion of individual action’. The control is made by customs or organised institutional forms (credit schemes, land tenure etc.) that are justified by a social consensus of opinion. Our framework differentiates two types of institutions: those for acquiring resources and those related to reaching markets.
We conducted a case study in 2 districts of Son La province as part of an ACIAR project focusing on improving beef cattle production. Our results are based on detailed qualitative interviews conducted in 2011 and 2012 with 8 farmers, 2 traders, 4 consumers and 10 government authorities. Major official documents were also analysed at the provincial, district, commune and village scales.

Access to grazing land is an important factor of the competitive advantage of the extensive cattle production systems in the highlands. It is recognised by traders and consumers as being responsible for the taste and tenderness of the meat. It is also a major factor in reducing production costs. However, the institutional organisation of access to those lands is weak. Grazing lands are not formally recognised, and producers face a lot of uncertainty in using them. To promote value chains likely to encourage local meat production, institutional innovations could be promoted, such as producers’ groups, contractual farming or local negotiations for land use planning.

The development of conservation agriculture (and, more generally, of sustainable agricultural systems in northern Vietnam) requires a more integrated management of land, taking advantage of locally available resources and promoting complementarities between agriculture and livestock activities. In recent times, grasslands have been largely neglected in comparison with cropping lands and forest cover in northern Vietnam. However, the emergence of new outlets for beef cattle, resulting from urbanisation and economic growth, might bring land users and local authorities to reconsider the value of grasslands, and to promote more sustainable extensive livestock production.

Keywords
Livestock, upland, institutions, value chain

Bibliography


Assessing agricultural sustainability of current farming systems to guide alternative management strategies: a case study in the highlands of Vietnam

D. Hauswirth*a, R. Kongb, F. Gramondc, D. Jourdaind, F. Affholtere, D. Q. Dangf, J. Weryg, P. Tittonelle,h

a CIRAD, UPR SIA, Avenue Agropolis, 34398 Montpellier Cedex 5, France
b PADAC Project c/o General Directorate of Agriculture, n° 56B, St 656, Toeu Laak, Toul Kork, Phnom Penh, Cambodia
c SUPAGRO, Avenue Agropolis, Montpellier, France
d CIRAD, UMR G-EAU, Avenue Agropolis, 34398 Montpellier Cedex 5, France
e CIRAD, UPR SCA, Avenue Agropolis, 34398 Montpellier Cedex 5, France
f NOMAFSI (Northern Mountainous Agricultural and Forestry Science Institute), Department of Agrarian Systems, Phu Ho Commune, Phu Tho Town, Phu Tho Province, Viet Nam
g CIRAD, UMR System #1230, Place Viala, 34060 Montpellier Cedex 2, France
h Wageningen University and Research Center, PO Box 563, 67000 AN Wageningen, The Netherlands

*Corresponding author: damienhh@gmail.com

In a context of intensive agriculture alongside land saturation, we surveyed farm households in Moc Chau district, Son La province, Vietnam, to assess the sustainability of current farming systems (Rasul and Thapa 2004) and to identify limiting factors and possible leverage for further sustainable intensification of agriculture based on conservation agriculture (CA) options.

Within 5 communes chosen to represent a diversity of agroecological conditions, we selected 11 villages along a spectrum of farming activities from specialisation in major crops (maize or tea) at one end to diversification at the other (Fig. 1; Table 1).

We interviewed members of 211 farm households using a quantitative economic questionnaire designed to capture the structural and functional aspects of a farm while providing data to calculate a set of sustainability indicators at the farm level. Following López-Ridaura et al. (2002), we derived these indicators from a framework designed to cover all sustainability attributes and critical issues formerly documented at district level (Table 2). Although providing indirect information on ‘pressure’ rather than direct information on process, these indicators were selected to be simultaneously ‘light’ (not requiring field measurements) and of practical use to guide the design of innovations to be proposed to farmers and the selection of potential beneficiaries.

We assumed that sustainability issues vary alongside structural aspects of the farming systems (e.g. constraints and opportunities in access to means of production) and their functional consequences.
Figure 1. Agroecological zones of Moc Chau District: locations of surveyed communes.

Zone 1: Poorly accessible, low elevation (0–600 m a.s.l.), 2 crops per year, low population density, remaining forestland.
Zone 2: Medium elevation (600-1000 m a.s.l.), medium to high population density, only 1 maize crop per year possible on steep slopes.
Zone 3: High elevation (900-1100 m a.s.l.), densely populated hilly plateau, specialised intensive agriculture.
Zone 4: High-elevation mountains (>1000 m a.s.l.), low population density, manual maize monocropping on steep slopes.

Communes surveyed: Tan Lap (TL), Chieng Hac (CH), Moc Chau (MC), Phieng Luong (PL), Chieng Khoa (CK).

Table 1. Main characteristics of the villages surveyed.

<table>
<thead>
<tr>
<th>Commune (inhabitants. km²)</th>
<th>Village</th>
<th>Zone Elevation (m a.s.l.)</th>
<th>Mean farm size (ha)</th>
<th>Dominant crops (N° cropping seasons per year)</th>
<th>Tea area: % of land (year of planting)</th>
<th>Dominant ethnic group</th>
<th>Accessibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chieng Hac (63)</td>
<td>Ta So</td>
<td>4 900–1200</td>
<td>1.6</td>
<td>Maize (1)</td>
<td>–</td>
<td>Hmong</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Ta Niet</td>
<td>1 500–900</td>
<td>1.4</td>
<td>Maize (1), vegetables</td>
<td>–</td>
<td>Kinh ++</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Pa Phang</td>
<td>1 450–900</td>
<td>1.6</td>
<td>Maize (1 &amp; 2), rice (2)</td>
<td>–</td>
<td>–</td>
<td>++</td>
</tr>
<tr>
<td>Chieng Khoa (67)</td>
<td>Tin Toc</td>
<td>1 500–750</td>
<td>1.4</td>
<td>Maize (1), rice (2)</td>
<td>10 (2001, 2004)</td>
<td>Thai (Muong)</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Pieng Sang</td>
<td>2 600–900</td>
<td>1.7</td>
<td>Maize (1), tea</td>
<td>24 (1996)</td>
<td>Dao ++</td>
<td>++</td>
</tr>
<tr>
<td>Tan Lap (94)</td>
<td>Ban Hao 1</td>
<td>2 800–1200</td>
<td>1.1</td>
<td>Tea, maize, rice (1)</td>
<td>46 (1996, 2003)</td>
<td>Native Thai</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Ban Hao 2</td>
<td>2 900–1200</td>
<td>1.1</td>
<td>Tea, maize (1)</td>
<td>50 (2003)</td>
<td>resettled Thai</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Nam Tom</td>
<td>2 900–1200</td>
<td>1.1</td>
<td>Tea, maize (1)</td>
<td>50 (2003)</td>
<td>Thai ++</td>
<td>++</td>
</tr>
<tr>
<td>Moc Chau (250)</td>
<td>Co Do</td>
<td>3 1000</td>
<td>0.5</td>
<td>Tea</td>
<td>30 (1960)</td>
<td>Kinh</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Tien Tien</td>
<td>3 1000</td>
<td>0.2</td>
<td>Tea</td>
<td>100 (1960)</td>
<td>–</td>
<td>++</td>
</tr>
</tbody>
</table>

We used principal component analysis complemented by hierarchical cluster analysis (Tittonell et al. 2010) to identify structural farm types. We then compared farm types for each selected sustainability indicator (Bonferroni’s test at P = 0.05). Finally, we considered sustainability issues and leverage to manage sustainable alternative systems for each identified farm type.
Table 2. Sustainability indicators.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Criterion</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>Agronomic efficiency</td>
<td>Crop return on investment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maize and tea yields</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maize return on inputs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Agronomic N efficiency for maize</td>
</tr>
<tr>
<td>Economic efficiency</td>
<td></td>
<td>Net farm and household incomes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Labour and land productivity</td>
</tr>
<tr>
<td>Stability, resilience,</td>
<td>Economic and biological diversity</td>
<td>Nº of livelihood, agricultural (breeding, cultivation) and non-farm activities</td>
</tr>
<tr>
<td>reliability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental</td>
<td>Intensity of N application</td>
<td></td>
</tr>
<tr>
<td>vulnerability</td>
<td></td>
<td>Fertiliser N recovery efficiency in maize grain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intensity of herbicide use (farmed and maize land) and insecticide applications</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Livestock pressure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Proportion of sloping land</td>
</tr>
<tr>
<td>Economic and social</td>
<td>Household poverty and opportunity income ratio</td>
<td></td>
</tr>
<tr>
<td>vulnerability</td>
<td></td>
<td>Sensitivity to labour costs, price of fertiliser, prices for tea and maize</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potential inheritance of land and capital by children</td>
</tr>
<tr>
<td>Adaptability</td>
<td>Capacity for change</td>
<td>Net income available per person</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Debt ratio and amount of ongoing loans</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ratio of farmed land under land use restriction</td>
</tr>
<tr>
<td>Self-reliance</td>
<td>Independence, autonomy</td>
<td>Dependence of household income on farming (%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Input consumption and intensification level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dependence on waged labour-force</td>
</tr>
<tr>
<td>Equity</td>
<td>Distribution of land</td>
<td>Apparent farm situation for distribution of land by reference to the mean observed land labour ratio among surveyed farms at village, commune and survey scales</td>
</tr>
</tbody>
</table>

We identified 5 farm types, which differ in resource endowments, constraints in access to means of production, short-term strategies to deal with those constraints, long-term positioning (Table 3) and sustainability issues. We also found that a differentiation of farming systems at the village level based on access to land and capital is occurring.

Farm types 1 and 2 represent under-resourced farmers constrained mostly by land and capital, with weak access to mechanised traction. Farmers of type 1 rely on off-farm activities to supplement household income, thus exacerbating labour constraints. Farmers of type 2 rely exclusively on specialised agriculture, mostly crops. They meet peak labour needs through share-cropping. Both types had the lowest land-labour ratio. Both types face a number of sustainability issues, among which the most critical in the short term is high social and economic vulnerability with low capacity to mobilise capital and mitigate market risks.

1 Most of displaced Thais people who arrived recently belongs to type 1
### Table 3. Framework for household categorisation on a structural and functional basis.

<table>
<thead>
<tr>
<th>Type</th>
<th>Economic wealth</th>
<th>Priority objective</th>
<th>Means of production</th>
<th>Farm long-term strategic orientations</th>
<th>Main livelihoods</th>
<th>Strategies to overcome constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (n = 34)</td>
<td>Insecure poor</td>
<td>Subsistence; supplement farm income</td>
<td>Labour, capital</td>
<td>Constrained agricultural specialisation</td>
<td>Small-scale cropping and animal systems</td>
<td>Migration, selling labour</td>
</tr>
<tr>
<td>2 (n = 43)</td>
<td>Secure poor</td>
<td>Market; mitigate risk</td>
<td>Labour, (land)</td>
<td>Agricultural diversification</td>
<td>Extensive small-scale animal systems. Intermediate input-level cropping system</td>
<td>Contract farming, loans</td>
</tr>
<tr>
<td>3 (n = 25)</td>
<td>Intermediate</td>
<td>Labour, capital</td>
<td>Land</td>
<td>Economic diversification</td>
<td>Permanent or seasonal employment. Temporary services to agriculture. Small-scale trading or processing</td>
<td>Rent or buy land</td>
</tr>
<tr>
<td>4 (n = 53)</td>
<td></td>
<td></td>
<td></td>
<td>Agricultural intensification</td>
<td>High-input-level–based cropping systems. Small-scale intensive animal systems (pigs)</td>
<td></td>
</tr>
<tr>
<td>5 (n = 56)</td>
<td>Richest</td>
<td>Market; earn further income</td>
<td>Land, capital</td>
<td>Economic diversification</td>
<td>Large-scale trading, agricultural product processing, cash or input provider</td>
<td>Motorisation, hiring daily or seasonal workers, rent out land or equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Market-driven agricultural specialisation</td>
<td>Large-scale intensive animal systems (cattle, poultry, pigs) and cropping systems</td>
<td></td>
</tr>
</tbody>
</table>

Hence, the average income earned by those farmers was below the international poverty threshold (1.25 USD/person/day), and 1/3 of them were earning a lower income than they would earn if permanently employed at the minimum legal wage (70 USD/month/worker).

Beyond the reasonable assumption that farmers of both types might move to other sectors if given the opportunity, we identified possible leverage to reduce their vulnerability. Farmers of type 1 would benefit from permanent off-season employment. A 50% increase in the daily wage would increase their household income by 16% on average. Farmers of type 2 would benefit from innovations that allow the intensification of animal systems and that increase labour productivity. Mitigation of production and market risks with better access to credit would reduce the vulnerability of both types.

Farm type 3 has a low to moderate resource endowment. Access to sources of non-farm income (mainly permanent employment, political responsibilities or retirement pension) allows farmers to overcome labour constraints by hiring workers (on average, 1 full-time-equivalent [FTE] worker for 2 months/year).
However, they had the most limited diversity of income sources among all farm types and were at risk of falling into poverty. In common with farmers of types 1 and 2 they face low labour productivity, sensitivity to variations in tea prices and the risk of being unable to pass on their farms equitably to their children.

Farm type 4 has a moderate to high resource endowment. Farmers rely on intensive cropping systems and intermediate-scale animal systems. They overcome labour constraints by hiring workers, on whom they are more dependent than farmers of other farm types (mobilising on average 1 FTE worker for 5 months/year). They are also the most dependent on cropping sloping land, thus facing the highest risks of nutrient losses from erosion. Although the biggest consumers of agricultural inputs, they had the lowest input-related agronomic efficiency, applying twice as much N on maize fields as other types while having the lowest N agronomic efficiency and N fertiliser recovery in grain yield. They had the most intensive use of herbicides and N, and their income was proportionally the most sensitive to variations in fertiliser prices, labour costs and maize yields and prices.

Farm type 5 also has a moderate to high resource endowment but incorporates economic diversification. Farmers engage in non-farm activities (political responsibilities, skilled agricultural services and large-scale trading or processing), large-scale intensive animal systems or both. They manage more diverse cropping and animal systems than farmers of the other farm types. They gained the highest return on agricultural inputs as a result of their high yields and efficient use of external inputs.

We found evidence of environmental threats at the farm level that need to be further investigated and monitored:

- Chemical weeding was practised by 79% of all surveyed farmers. All farm types used a similar intensity of herbicides on maize fields: mainly atrazine (82% of maize producers), at an average rate of 5528 g a.i./ha, >3x the maximum limit in the USA (Ribaudo and Bouzaher 1994). This suggests possible contamination of groundwater and streams that needs to be investigated.

- Insecticides were used systematically on tea and intensive vegetable production but not on other crops. The intensity of insecticide use on tea, and hence the risk of residues in the product, was, on average, similar across all farm types. This may allow room for improvement through the use of integrated pest management rather than programmed insecticide application.

- Farmers of farm type 5 were developing large-scale intensive animal systems (up to 13.6 tropical livestock units/ha), the possible side-effects of which should be monitored.

Our findings also have practical implications for the design and extension of CA options based on the diversity of constraints and opportunities farmers have to deal with:

- All farm types showed low fertiliser-N recovery rates in maize grain (7%–10%), indicating potential improvement through CA options with integrated nutrient management (Ladha et al. 2005).
• CA systems to be designed for farmers of farm types 4 and 5 should incorporate animal or motorised traction. Those for farmers of types 1–3 should emphasise manual agriculture. Conversely, including chemical weeding for all farm types would not bring major difficulties.

• Farmers of farm types 4 and 5 would benefit from CA systems that allow better integration of cropping and animal systems.

• Despite higher investments in farming by farmers of farm types 4 and 5, inputs and external labour accounted for a similar proportion of the commercial value of agricultural products of all farm types except type 3. This may imply some trade-offs between investments in agricultural inputs and hired workers. It also implies that CA options may not be relevant if the improvement of land productivity is the only target.

• CA options would be more relevant to farmers of farm type 4 in the short-term. Although farmers of farm types 1–3 would need support, they face short-term economic constraints that are of higher priority than investment in long-term soil fertility. In contrast, although farmers of farm type 5 can afford to invest in new technologies, they already engage in other activities than agriculture, and thus may have less interest in agricultural innovations.

This research was funded by AFD through the ADAM project and PAMPA-RIME Research Program 3.

Keywords
Farming systems, agricultural sustainability, indicators, typology, Vietnam

References


Redox potential (Eh) and pH as indicators of soil conditions: possible application in design and management of conservation agriculture cropping systems

Olivier Husson*1

1 CIRAD/PERSYST/UR SIA, Montpellier, FRANCE

*Corresponding author: olivier.husson@cirad.fr

Conservation agriculture (CA) is based on ‘ecological intensification’, i.e. the mobilisation of ecological processes to increase some ecosystem functions (Doré et al. 2011). Designing and managing CA cropping systems requires a good understanding of these ecological processes, how they participate in the functioning of the soil/plant/microorganism systems and how they could be activated. In this respect, agronomists must integrate a wide range of disciplines across scales and in contrasting environments. The identification of parameters that could bridge the gap between disciplines and transcend scales would be helpful.

pH, which characterises the activity of protons (H⁺), is a key parameter in many biological processes. However, the chemistry of living organisms relies even more on oxidation–reduction reactions, i.e., the transfer of electrons, than it does on acid–base reactions (Dietz 2003). Oxidation–reduction conditions are classically assessed by measuring the redox potential (Eh), expressed in volts. Eh is commonly used in a large range of disciplines dealing with living organisms, such as microbial ecology, geochemistry, biogeochemistry, bioenergetics, hydrobiology, soil science, physiology and ecophysiology. Surprisingly, in contrast with pH, which is regarded as a master variable and classically used, Eh is rarely used in agronomy. Eh studies remain limited to reduced environments such as paddy soils, and studies of Eh in aerobic conditions are exceptional.

A trans-disciplinary review revealed that Eh and pH could be used to characterise ‘ideal’ soil conditions (Fig. 1) favourable for the development of plants and microorganisms, optimising nutrient solubility, humification and mineralisation processes, reducing pest pressure and minimising the solubility of toxic elements (Husson 2012). In such ‘ideal’ conditions, plants function at their optimal physiological level, with a high energetic efficiency. Photosynthetic products are devoted mainly to biomass production, thus increasing leaf area and photosynthesis. In contrast, plants in non-optimal conditions need to adjust Eh–pH in their rhizosphere, at a high energetic cost (Husson 2012).

We therefore propose the use of Eh and pH as major indicators of soil conditions, especially during the transition period from intensive agriculture to CA.
Figure 1. Theoretical ‘ideal’ Eh–pH soil conditions. Based on a trans-disciplinary literature review (Husson 2012).

Figure 2. Changes in soil Eh induced by CA practices in a sandy soil (2% clay) in Tourraine, France. Eh was measured in a 1:2 soil:water extract with a Consort C3050 analyser (n=3).
This Eh–pH perspective can explain the central role of biomass turnover and organic matter cycling in CA (Séguy et al. 2006, 2012) by their fundamental roles in pH and Eh regulation: organic matter leads to neutral pH and lowers Eh (Husson 2012).

CA cropping systems design could be driven according to these processes: design would aim at adjusting soil Eh–pH conditions (using plant biomass) to optimal levels for plant production. Although Eh measurement raises problems and requires standardised protocols, especially in aerobic soil conditions, preliminary results indicate that CA practices modify soil Eh and pH towards ‘ideal’ conditions (Fig. 2). This opens challenging and exciting paths for the design and management of CA cropping systems.

Keywords
Agronomy, soil/plant/microorganism systems

References


Chapter 2
Design of Agricultural Systems

Subtopic 3
Use of models

Vietnam
Tea experiment in Phu Tho

Nguyen Xuan Cuong, Phu Tho, 27/10/2010
Keynote 4: Reconciling experimentation and modelling in the design of alternative agricultural systems

Pablo Tittonell*1, Felix J.J.A. Bianchi1, Jeroen C.J. Groot1, Egbert A. Lantinga1, Johannes M.S. Scholberg1 and Walter A.H. Rossing1

1Farming Systems Ecology, Plant Sciences, Wageningen University, PO Box 563, 6700 AN Wageningen, The Netherlands

*Corresponding author: pablo.tittonell@wur.nl

Abstract

Linking experimentation, field data collection and modelling is essential in the design of alternative agricultural systems. Most alternative agricultural systems, such as conservation agriculture (CA), organic farming or ecologically intensive low-input systems, rely largely on biologically mediated processes and ecological-based support and regulation services. Since deterministic modelling of such systems typically fails to reproduce their intrinsic behaviour and complexity, experimentation remains indispensable in many cases. We show through examples that field measurements, experiments and modelling can support each other when one is diagnosing a specific problem or exploring viable alternatives as part of the design of, for example, disease-tolerant cropping systems, pest-suppressive landscapes or closely integrated crop–livestock farming systems. Expert knowledge and farmer perceptions may provide essential clues for validating models at scales transcending the field-plot scale. Instead of segregating modelling from field observations, experiments or practitioner knowledge, we propose a framework for their integration in the design of alternative agricultural systems.

1. Introduction

When we were asked to provide a keynote paper on the topic suggested by this title, the first question that came to mind was ‘What needs to be reconciled?’ We have many reasons to think that there is no divide necessary between experimentation and modelling. After all, what is an experiment if not a simplified model of a system at 1:1 scale? Moreover, experiments are meaningful only when they are designed on the basis of the statistical model with which the data collected from the experiment will be analysed. In day-to-day scientific practice, experimentation and modelling are often inseparable. They constitute a methodological continuum that allows for flexible and cost-effective initial assessments, such as using models for the design of experiments, experimenting with models or running experiments to derive parameter values or to calibrate and test models.
Granted, there is often some kind of disciplinary animosity between pure ‘modellers’ and classical ‘agronomists’, who regard each other with distrust for their respective methods, which tends to be based on a lack of awareness and on misconceptions. Therefore, there is a need for science to continue to evolve, as both pure modellers and classical agronomists are becoming museum pieces, but fortunately an increasing diversity of methods for integrated assessments is emerging.

Ecology provides good examples of integration between experimentation and modelling. In ecology, which we define here as quantitative biology, measurements of stocks, flows, concentrations, states, populations and diversity are essential to characterise ecosystem behaviour quantitatively. Experiments or sampling schemes designed to measure these variables and their determinants are essential in this field. Similarly, agronomy relies on experiments for a range of reasons, from testing hypotheses regarding the functioning of the agricultural system to testing the field performance of a certain practice, technique or germplasm. On the other hand, models are irreplaceable when one is analysing systems across scales (in space and time), when exploring alternative scenarios and when feedback mechanisms are to be captured in the analysis. Models are a valuable tool when one is analysing trade-offs -although these can be analysed by other means as well. When the problem at stake is described by many variables fluctuating simultaneously and interacting with each other, modelling is the best way to unravel such complexity. Finally, models are the only effective (scientifically rigorous) way to look into the future and to explore alternatives.

Passioura (1996) discussed key aspects of the marriage between models and experiments in agronomy in a special issue of the *Agronomy Journal* on this subject. Recently, Affholder et al. (2012) revisited this and other papers from that issue (e.g. Sinclair and Seligman) and showed examples of how experimentation and modelling can complement each other, proposing the use of ad hoc modelling and virtual experimentation to study crop yield variability and its causes in farmers’ fields. In both cases the discussion was centred around crop simulation models. In our view, the major synergies between models and experiments emerge when one is scaling up in space and time or exploring alternative systems. This keynote paper examines possible uses of models in combination with experiments or with on-farm data of different natures (biophysical measurements, management decisions, expert knowledge), moving from cropping systems to farms and landscapes, to inform the design of alternative agricultural systems.

2. Concepts: systems, models, analysis and design

Let us first define some key elementary concepts so as to avoid misinterpretations. A system is a limited portion of reality, in which we can identify components (or subsystems) interacting with each other and with the exterior environment through inputs and outputs. A model is a simplified representation of a system that enables us to study the system’s properties and behaviour.
The system itself (i.e. the limited portion of reality) is known as the ontological system, while the model (its representation) is a semiotic system. Moving from ontological to semiotic systems implies variable degrees of reductionism, and explicit choices in the level of detail in the model or the components and interactions to be represented. This in turn depends on the objectives for which the model is built, on the field of knowledge or discipline of the modeller, and on his or her subjectivity. Models can be thus developed with the objective of understanding a system (analysis) or contributing to systems design, the latter being the focus of this paper. While in research we analyse systems in order to enhance our understanding of the relationship between structures and functions, and ultimately infer their purpose, in design we move in the opposite direction (Fig. 1). The purpose is known, and through a process of knowledge synthesis we try to identify the necessary functions to fulfil such purpose, as well as the structures needed to sustain such functions.

**Figure 1.** The differences between research and design in the realm of agricultural systems.

![Diagram of research and design processes](image)

Although agroecosystems can be defined as cybernetic systems that are steered through human agency, a distinction should be made between systems that are purely mechanical and systems that depend on biological components such as microbes, or on stochastic drivers such as the weather. An engineer can easily design a radio on paper and, if the model design he or she uses is accurate enough, then a radio built from the design should work properly.
A typical example of this was the design of the first vehicles for space travel that could not be tested before they were put into orbit - no experimentation could be done, and yet in most cases the experience was successful (de Wit 1982).

In biological systems, uncertainties are large and predictions are less reliable. We study structures to understand functions. We come up with ways of describing the causality at play between structure and function and, thanks to experiments, with a probability of certitude associated with our statements. Experimentation is thus an essential step during the analysis and design of systems with important biological dimensions, such as agroecosystems.

Alternative and low-input farming systems, such as CA, organic farming or traditional smallholder agriculture, rely largely on organic resources and biodiversity for their functioning. Their biological dimension is thus of greater importance than in conventional systems, as they rely largely on organic matter decomposition or biological N\textsubscript{2} fixation for nutrient supply, on soil–root feedback or rotational carryover effects for suppression of soilborne diseases, on crop–livestock interactions for nutrient cycling or on natural agents for pest control. Some of such biologically mediated interactions may be lost in experiments conducted under controlled conditions, which simplify the actual agroecosystem (Fig. 2). Results from such experiments can be scaled up across diverse landscapes through the use of models, as the examples below illustrate. But models of biological systems remain highly uncertain and need repeated testing through experimentation.

**Figure 2.** Examples of models dealing with abiotic interactions at field, farm and landscape levels. An experiment is itself a simplified model of the actual agroecosystem.
3. Examples of integration

3.1 Yield gap analysis

A common example of the combination of models and experimental data is the assessment of crop yield gaps (e.g. Tittonell et al. 2008; Affholder et al. 2012). Although experiments -or, rather, yield measurements- in farmer fields are irreplaceable in yield gap analysis, well calibrated crop models can be used to estimate the reference yields so as to assess overall yield gaps. Such reference yields are often termed ‘potential yields’, or ‘yield potential’, or ‘water-limited yields’ (van Ittersum et al. 2012). Potential yield is the theoretical maximum yield attained by a given crop cultivar in a certain environment, as determined by radiation, temperature and crop genotype. Water-limited yields are determined by these factors and by water availability during the season -although often the total annual or seasonal rainfall is used in their calculation. Both potential and water-limited yields are virtually impossible to obtain under experimental conditions, even with irrigation, but they can be easily estimated by most crop simulation models of today.

Modelling is used in these cases to study the portion of yield variability that is known -for example, due to light, water or nutrients- and thus to estimate the impact of uncontrolled variables such as weeds, pests, toxicities, soil compaction or micronutrient deficiencies. Maize yields measured in farmers’ fields in the Kenya highlands were highly variable and tended to increase with the amount of water available for crop uptake during the season (Fig. 3A). Simple observation of the data distribution indicates that the maximum maize yield attainable by farmers is about 4 Mg ha\(^{-1}\) of grain when water availability exceeds 600 mm, but most fields yield 2 Mg ha\(^{-1}\) or less irrespective of rainfall (median yield is 1.4 Mg ha\(^{-1}\)). From these observations it is not possible to estimate a reference yield to quantify the average yield gap in the region. Simulations performed with the crop–soil model DYNBAL (Tittonell et al. 2006) allowed us to estimate attainable yield in each field at each level of water availability, provided that nitrogen was not limiting. These yields then correspond to the water-limited yield level. A boundary line logistic model fitted to the simulated water-limited yields indicates a maximum reference yield level of 7.4 Mg ha\(^{-1}\).

Comparing simulated and measured yields showed that the yield gap between maximum farmer yields and maximum attainable water-limited yields amounted to 3.4 Mg ha\(^{-1}\), whereas the gap between median farmer yields and water-limited yields was as much as 6 Mg ha\(^{-1}\). If the modelling results are correct, proper agronomic management and technologies for yield intensification should thus allow maximum yield increases of 6 Mg ha\(^{-1}\) in the region, when seasonal rainfall is >600 mm. Such yield increases were possible in some fields through the application of recommended rates of N, P and K fertilisers (Fig. 3B), indicating that the model results were realistic for this region.
Yet, although positive responses to fertilisers were measured in most fields, the yield potential described by the logistic yield envelope could be realised in only a few cases, owing to the likely effect of other yield-limiting factors that were not accounted for in either the model or the design of the field experiments.

This calls for further experimentation to test new hypotheses on yield-limiting factors, in which models and experiments can be used iteratively.

**Figure 3.** Measured and simulated maize grain yields as a function of seasonal crop-available water (serial water balance) in the Kenya highlands. (A) Simulated water-limited yields and actual yields measured in farmers’ fields. (B) Simulated water-limited yields and yields measures in micro-plots established in the same fields and receiving recommended NPK fertilisation rates. The solid line is a logistic boundary model (yield = 7.4 / (1 + 100 * e\(^{-0.012\cdot\text{available water}}\)), in Mg ha\(^{-1}\)). The dashed lines are hand-drawn to indicate maximum and median yields under current farmer management.
3.2 Mixing potato cultivars to increase longevity of cultivars resistant to late blight

Plants can defend themselves against microorganism attack. Many of their defence mechanisms are polygenic and provide levels of protection that vary from low to absolute. Another set of defence mechanisms can be traced back to one or several clearly identifiable resistance, or R, genes. The defence provided by an R gene can be overcome if, in the pathogen population, a mutation occurs in a so-called avirulence gene. Currently, there are about 20 known R genes against Phytophthora infestans, the causal organism of potato late blight. The longevity of these genes, once introduced into potato cultivars for human use, is therefore an important common good. Field mixing of genotypes with different genetic backgrounds is a powerful means to reduce the rate of disease spread. Skelsey et al. (2010) investigated the contribution of mixing cultivars at different spatial scales, from the field scale, where resistant and susceptible genotypes can be alternated, to the landscape scale, where clustering of genotypes in fields or regions resulted in different spatial strategies.

Experiments with mixing strategies at the landscape scale (in this case some 35 km²) are extremely difficult, if not impossible, as spores discharged from a source become highly diluted and difficult to recover at distances of several kilometres. However, a combination of spatially explicit models evaluated at the field scale, a model of spore survival during exposure to solar radiation and physical models of particle dispersal due to atmospheric transport tested at relevant spatial scales provide a means to investigate the effects of different mixing strategies.

The epidemiology of P. infestans was simulated by coupling a crop growth simulator with a model that describes the progress of the pathogen population through various life stages as a function of temperature and humidity, taking into account the distribution of spores produced on a plant across nearby plants using a dispersal-distance function (see previous section; Skelsey et al. 2009). In a field experiment using 5 potato cultivars and 2 strains of the pathogen, potato plants in 3.75 m x 3.75 m plots were infected, and the progress was monitored weekly. Results simulated by an epidemiological model gave a plausible representation of reality (Fig. 4). This model was then combined with a tested atmospheric transport model (Skelsey et al. 2008) and a model of spore survival (Mizubuti et al. 2000).

Different landscapes were generated within the model by assuming the landscape to consist of 100 m x 100 m cells containing a resistant genotype, a susceptible genotype or a non-host. Different landscapes were created by varying 5 landscape variables: the proportion of potato, the proportion of susceptible potato, field size, field shape and the clustering of the fields. For all combinations of landscape variables, resistant and susceptible genotypes were assumed to be mixed within a field or between fields. The landscapes and the genotype mixing strategies were tested with 10 years of weather data from Wageningen, the Netherlands. The results showed how the landscape variables affected the level of disease at the end of the season following invasion of the pathogen at random locations.
The most effective spatial strategies for suppressing disease spread were those that reduced the area of potato or increased the proportion of a resistant genotype. Clustering potato cultivation in some parts of a region, either by planting in large fields or clustering small fields, enhanced the spread within such a cluster while it delayed spread from one cluster to another. However, the net effect of clustering was an increase in disease at the landscape scale. The planting of mixtures of resistant and susceptible cultivars was a consistently effective option for creating potato-growing regions that suppressed disease spread. It was more effective to mix susceptible and resistant cultivars within fields than to plant some fields entirely to a susceptible cultivar and other fields to a resistant cultivar at the same ratio as at the landscape level. When resistant and susceptible genotypes were spatially separated, distances of at least 16 km were needed to avoid infection.

Figure 4. Observed (◊) and predicted (-) disease progress curves of potato late blight epidemics under field conditions in the Netherlands in 2002. Vertical lines represent the standard deviation of the observed mean blight severity. Top row, fields with isolate IPO428-2; second row, with isolate IPO82001. Cultivars from left to right are Agria, Bintje, Remarka, Sante and Azziza.

3.3 Pest-suppressive landscapes

The concept of pest-suppressive landscapes is based on observations that herbivorous insect populations build up more slowly in some landscapes than in others. This can be related to bottom-up or to top-down processes. Bottom-up processes involve effects of (host) plants on herbivores; examples of such effects may require the availability of few suitable host plants, poor host plant quality or habitats that cannot easily be colonised by herbivores. Top-down processes involve the activity of natural enemies, which may effectively control the herbivore population.
A central notion underlying the concept of pest-suppressive landscapes is that the various habitats in the landscape should not be considered as closed systems but as being linked via dispersal of herbivores and their natural enemies. Indeed, both herbivores and natural enemies often need resources and conditions provided by multiple habitats to fulfil their life cycle and can, as such, be considered habitat linkers. In this section we focus on how experiments and modelling have been used to quantify dispersal and to extend the application of such data in the domain of pest-suppressive landscapes.

Common methods used to quantify dispersal rely on mark-capture or mark-recapture experiments. In mark-capture experiments, individuals are marked in the field. Mark-recapture experiments entail the release of marked individuals and the subsequent (re)capture after a fixed time. Even though a mark-capture experiment does not give information on the actual track that individuals have followed, merely the start and end points, they often give the best data available. Schellhorn et al. (2008) conducted a mark-capture experiment with the parasitoid *Diadegma semiclausum*, which can control the diamondback moth (*Plutella xylostella*) in broccoli fields. The parasitoids were marked by spraying strips of broccoli with fluorescent dye, and samples were taken with a suction sampler 48 h later. Although the resulting dispersal-distance function provides valuable information about the displacement of parasitoids, the implications of these results remain somewhat limited without the possibility to project these in time and space.

In a follow-up study, Bianchi et al. (2009) fitted 3 distributions to the dispersal-distance data: the normal, the negative exponential and the square-root negative-exponential distributions. These distributions respectively have thin, intermediate and fat tails; that is, the square-root negative-exponential distribution redistributes a larger proportion of individuals over large distances than the normal distribution. Interestingly, all 3 models provided more or less similar fits to the data. However, when the implications of the 3 fitted distributions for the rate of spread of a virtual parasitoid population were explored using a simple simulation model, the distributions resulted in major differences in the time needed to cross a predetermined distance. This finding highlights the importance of the shape of redistribution functions, and of the collection of data that enable discrimination between different functions. The implications of the rate of spread (often referred to as ‘dispersal capacity’ or ‘motility’) of predators for pest suppression were further explored by using a spatially explicit simulation model (Bianchi et al. 2010). Simulations suggested that early crop colonisation by predators, when the pest density in the crop is still low, typically results in effective pest suppression, because the removal of a single herbivore early on can prevent all its future progeny. In the case of fast reproducing pests, such as aphids and whiteflies, there is only a limited time-window before the pest population reaches such a high density that its reproduction capacity is too high to be reduced by predation alone, and pesticides are needed. As pesticide applications harm not only pests but also often their natural enemies, this may undermine the potential of natural pest control in the field in the rest of the growing season (Settle et al. 1996).
3.4 Redesign of farming systems

Targeted adjustment of farming systems to better achieve various production and environmental objectives is complicated by the large array of farm components involved, the multitude of interrelations among these components and the associated farm and policy constraints. This complexity complicates the evaluation of relations among various farm performance indicators and of the consequences of adjustments in farm management. The FarmDESIGN model (Groot et al. 2012) aims to overcome such limitations by coupling a bio-economic farm model that evaluates productive, economic and environmental farm performance to a multi-objective optimisation algorithm that generates a large set of Pareto-optimal alternative farm configurations. The model has been implemented for a wide range of arable, mixed and dairy farming systems in Asia, Europe and Latin America that differ considerably in complexity, size and intensity. It was used to diagnose existing farming systems (for instance, by analysing the nitrogen cycle; Fig. 5A), to show trade-offs among various objectives, and to identify alternative farm configurations that performed better than the original farming systems (Fig. 5B).

The model was initially developed in close cooperation with farmers, initially to support farm diagnosis through the use of farm data. More recently it was expanded to systematically explore viable options for future development on the basis of the Pareto-based Differential Evolution algorithm (Groot et al. 2010; Groot and Rossing 2011). On-farm action research using models often faces the challenge of effectively implementing models while keeping outputs obvious and relevant to stakeholders (Sterk et al. 2006; Andrieu and Nogueira 2010). Models and indicators can be evaluated in terms of design, output and end-user validity (Bockstaller and Girardin 2003). Design validation addresses the scientific soundness of model calculations. A major issue during design validation is selection of the correct combination of algorithms required to calculate a diverse set of indicators relating to environmental, economic and social aspects of the farming system. The calculations in the FarmDESIGN model are primarily annual balance calculations and aggregations based on farm data. Other calculations concerning feed balance, manure decomposition, nutrient losses from manure and soil organic matter breakdown are based on algorithms that are founded on existing, accepted scientific approaches.

Output validation is concerned with the question of whether the model produces realistic and reliable results which can be evaluated, for instance, by comparison with measured data. In the case of the FarmDESIGN model, output validation is to a large degree straightforward, since carbon and nutrient balances and flows are directly derived from measured or estimated quantities of carbon and nutrients in specific farm components and materials imported into or exported from the farm. Economic and labour balance calculations use only reported costs, prices and labour inputs. The uncertainties in outputs of the model reside in the quality of the input data and in the calculations of feed balance, manure degradation, nutrient losses from manure and soil organic matter breakdown.
The parameterisation of these algorithms is difficult, in particular on farm, so that output validation will depend on assessments based on expert knowledge, as performed in this case by a farm advisor and the farmers on the basis of their administrative records.

**Figure 5.** Typical output of the FarmDESIGN model (from Groot et al. 2012). Flow diagram: nitrogen flow on a 100 ha mixed organic farm in The Netherlands. Graph: set of farming systems alternatives from an optimization aiming to minimise soil N loss and maximise operating profit (other objectives involved not shown). Red square marks original farm configuration. Dots show farm objective values performing better in at least one objective (green dots) or all objectives (blue dots).
Defining a farm in the model and evaluating modelling results typically requires 2 or 3 sessions of a few hours with the farmer.

In between sessions the researchers or advisors parameterise and run the optimisation algorithm. Additional information may be generated. This iterative process can be embedded in consecutive adaptive learning and design cycles (Groot and Rossing 2011), in which all modelling steps are repeated, for instance annually, so that changes in farm conditions and external influences such as prices and policies can be included in a continuous farm improvement process. We discussed the models’ results with the farmers for their validation of both the analysis of the original situation and the optimisation results representing alternative future options.

The analysis of the current situation highlighted some points that the farmers recognised. Inspection of the optimisation results with farmers and other stakeholders such as farm advisors warrants special attention in the participatory process, because the amount of output data can be overwhelming and could lead to confusion. Therefore, accurate selection and presentation of data are crucial, preferably supported by easy-to-use and powerful data visualisation tools (e.g. Kollat and Reed 2007; Castelletti et al. 2010).

4. Concluding remarks

The various examples presented above illustrate the importance of linking experimentation or field data gathering and modelling during the design of alternative agricultural systems, in particular when these are dominated by biological processes that cannot be readily controlled. Most of the currently emerging alternative agricultural systems, such as CA, organic farming or ecologically intensive low-input systems, rely largely on biologically mediated processes, and aim to provide ecological services of support and regulation.

Experimentation is essential in such cases, as deterministic modelling will likely fail to reproduce the specific behaviour of such systems. Field measurements, experiments and modelling can be combined in the diagnosis of a specific problem (section 3.1). Designing disease-suppressive cropping systems (s. 3.2) or pest-suppressive landscapes (s. 3.3) is not possible without field measurements, whereas scaling up the impact of a certain spatial configuration of biodiversity is not possible without models.

Field measurements and experiments may not be enough to validate the results of our bio-economic models of farm systems, and expert knowledge and farmer perceptions may provide the right information in such cases. Thus, instead of segregating modelling from field measurements, experiments or participant knowledge, we propose a framework for their integration, through defining steps in the design of alternative agricultural systems (IDEAS):
Identify the problem

Diagnose the current situation

Explore alternatives

Assess feasibility and impacts

Select best options

While steps I, D and E correspond to the phase of analysis, steps E, A and S correspond to synthesis (Fig. 1).

Both analysis and synthesis are necessary phases in the design of systems that make intensive use of the natural functionalities that ecosystems offer (Doré et al. 2010). Models, field data, experiments and knowledge must be used in combination throughout this process. This is how we see experiments and models reconciled—and we hope for a long, enduring and intimate relationship.

References


Bianchi FJJA, Schellhorn NA, van der Werf W. 2009. Predicting the time to colonization of the parasitoid Diadegma semiclausum: the importance of the shape of spatial dispersal kernels for biological control. Biological Control 50: 267–274.


Introducing a supplementary crop during spring in the high-elevation valleys of the northern mountains of Vietnam would contribute to the intensification of agricultural production. The goal of our research was to assess its agro-climatic feasibility.

Assuming crop-related climatic constraints, we based a model of crop production (Figs 1, 2) on agronomic experiments implemented for calibration and evaluation. We ran a virtual experiment to test candidate crops (paddy rice, aerobic rice, maize and soybean) under the climates of 3 regions along an elevation gradient and following several management practices with different sowing dates.

We tested both irrigation during summer only with the introduction of a rainfed crop in spring, and irrigation during spring and summer with the introduction of an irrigated crop in spring, both of which practices are used in the mountains of Vietnam.

For each irrigation regime and for each of region and crop, we examined favourable sowing windows, that is, intervals of sowing dates that lower the risks associated with the spring crop. The timing of such windows indicates the climatic constraints on a given crop at a given place: the shorter the window is, the more difficulties farmers will have in taking advantage of it.

The results clearly confirmed that even if irrigation water is abundant, the climate of the mountains in Vietnam does not allow planting a spring crop everywhere.

Several risks were identified, including:

- crop destruction by lethally cold temperatures during the early vegetative stages
- delayed maturity if irrigated summer rice is sown after the recommended date
- decreases in yields due to low radiation and temperature during the first half of the season.
Figure 1. Conceptual model of grain yield limited by hydric contraints (Y lim).

Figure 2. Duration of the favourable window for sowing corresponding to a 80% probability to obtain a yield higher than 70% of potential one while harvesting before 5th July.

Under irrigated conditions, the simulated crop that best escaped these constraints was soybean, followed by maize and direct-sown rice. Transplanted rice was very sensitive to temperature constraints (Fig. 3).
Under rainfed conditions, the introduction of a spring crop was risky, especially on account of delays in seedling emergence and water stress during vegetative growth as a result of low rainfall during the early part of the season.

Figure 3. Duration of the favourable period for direct sowing and transplantation of rice under 3 different climatic conditions.

Soybean remained the shortest duration crop, but its simulated yield was strongly reduced by water stress. Under rainfed conditions, aerobic rice and maize were possible options only at lower elevations in all the regional climates studied (Fig. 4).

We sketched out the feasible area of spring crops and devised research perspectives aimed at increasing it.

Our findings will be useful for local intensification of agriculture in the study region.

Our work also confirms the value and effectiveness of an ad hoc modelling approach for agro-climatic studies to address agricultural intensification in the highlands of Vietnam.
Figure 4. Duration of the favourable sowing period for aerobic rice, soybean and maize by elevation when water is not limiting (left column) or limiting (right column) under different climatic conditions.

a) Cold and wet climate at Phu Ho

b) Intermediate climate at Van Chan

c) Hot and humid climate at Mu Cang Chai
Bibliography


Le QD, Luu NQ, 2007. Nghiên cứu áp dụng các biện pháp kỹ thuật nâng cao hiệu quả sử dụng đất ruộng một vụ vùng miền núi phía bắc Việt Nam (Study on application of technical approached to increasing efficiency of use rice field cropped one a year in the mountainous region of the north Vietnam). Science and Technology Journal of Agriculture and Rural Development 7: 79–82.

Can more irrigation help in restoring environmental services provided by upper catchments? A case study in the northern mountains of Vietnam

Damien Jourdain*, Esther Boere², Marrit van den Berg³, Dang Dinh Quang⁴, Cu Phuc Thanh⁵, François Affholder⁶

¹ UMR G-EAU, CIRAD - Asian Institute of Technology, Bangkok, Thailand
² Agricultural Economics and Rural Policy Group, Wageningen University, the Netherlands
³ Development Economics Group, Wageningen University, the Netherlands
⁴ NOMAFSI, Phu Tho, Vietnam
⁵ TUEBA, Thainguyen, Vietnam
⁶ CIRAD, UPR SCA, Avenue Agropolis, 34398 Montpellier Cedex, France

*Corresponding author: damien.jourdain@cirad.fr

Ecosystem services (ES) supplied by upper catchments in northern Vietnam, such as biodiversity reservoirs and catchment regulating functions, are under increasing pressure. Decollectivisation and the following redistribution of land, the liberalisation of markets and population growth are the main drivers (Folving and Christensen 2007). In particular, slash-and-burn cultivation, practised with shortening fallow periods and without compensating inputs, is posing a threat to these important ES.

To maintain or restore the ES, authorities are proposing that farmers set aside some of their cultivated sloping land in order to re-establish forests. This is far from easy for the small landholders, since it reduces the already scarce land available for food production. Moreover, it can increase the food insecurity and financial instability of most landholders, whose objectives are to produce enough to eat and sell the surplus. Larger landholders are more integrated with markets and are more able to give up some land. Re-establishment of forests would provide various ES such as biodiversity restoration, flood regulation and diminution of erosion loads on irrigation systems and towns downstream (Krieger 2001). Compensation for the additional services rendered would increase uplanders’ incentives to participate in ES programs. This is the principle underlying ‘payment for environmental services’, or PES (Engel et al. 2008).

The main objective of this abstract is to analyse the impact of an alternative land set-aside program for forest regrowth. This program involves compensating farmers for retiring some of their sloping agricultural land to natural forests by terracing part of their sloping rainfed land, with access to irrigation during 1 cropping season per year. (In this abstract, we consider only the case of natural forest, meaning that farmers are not expecting revenues from these newly forested areas in either the short or medium term.)
We expect that this program would allow farmers to increase production of staple crops on their remaining land and thus directly compensate for production losses caused by the reduced cropping area. We did not consider an increase in irrigated lowland area a realistic compensation mechanism, as most of the easily irrigable lowlands have already been appropriated.

In contrast, a substantial proportion of the existing sloping fields could be developed into terraces. We recognise that there are known physical limitations to the conversion of sloping land into terraces, such as soil type, soil depth and steepness, and do not anticipate a complete conversion of the sloping area into terraces. Yet the possibilities of terracing have often not been exhausted, on account of the large costs of linking additional terraces to water sources for individual farmers.

A recent analysis conducted in the mountainous Van Chan district in Yen Bai province identified 6 farm types contrasted by their access to land and water (Jourdain et al. 2011). Using mathematical programming, we developed farm models for those types. We investigated scenarios where farmers set aside, but still own, some land in the sloping areas of the catchment for forest regrowth, while some of their sloping land is transformed into terraces.

We first calibrated and validated the farm models against farm-level data collected in 2008 in 4 villages of the same district. Then we simulated the level of participation of the different types of farms in PES for different values of terraced area per area of land set aside. Participation was measured by the area of land converted into forest. For each scenario, we analysed the trade-offs between sloping land and terraces and the impacts on land use and revenues at the farm and village levels.

Our study contrasts with previous work in at least 3 ways. First, we have modelled a context in which most agricultural land is privately owned and where farmers cannot expand their agricultural land by deforestation, as it is now the case in large parts of the mountainous regions of northern Vietnam.

Second, a sizable proportion of farms in the mountainous areas of Vietnam practise some form of ‘composite swiddening’, an agroecosystem that combines upland crop and fallow rotation and downstream permanent wet rice fields into a single household resource system (Vien et al. 2009). In contrast, most PES analyses seem to concentrate on pure rainfed agriculture. Our model is designed to integrate pure rainfed agriculture and small portions of rainfed lowland rice agriculture.

Third, many PES case studies in mountainous areas consider mainly land diversion programs, whereby some land is set aside for reafforestation with financial compensation. Our study contributes to the existing literature on PES (Engel et al. 2008) by proposing different PES scenarios in which the farmers set aside some uplands in return for additional irrigation water from a public scheme built with external funds. Here, the use of external funds is justified by the additional provision of the ‘common good’ ES. The rationale behind providing more water instead of financial reward is that many farmers are still facing market imperfections and are really concerned about their food security.
In this context, compensating retired land by financial rewards may be less attractive than providing the means to maintain food production. Irrigation as practised in those mountainous areas relies mainly on gravity (the idea is to tap water flowing downhill instead of pumping water uphill), whereby irrigation of these new terraces would be limited to 1 cropping season per year.

This leads to a more sustainable PES scheme than yearly financial rewards for maintaining forest protection.

Results show that, given the assumptions of the model, increasing access to irrigated terraces as a way to compensate for land conversion to forest increases the participation of the poorest farmers in PES schemes and is more cost efficient than pure cash payments. This suggests that the present program, which is biased against the smallest landholders of the region, can be transformed into a win–win program that increases the forested areas and reduces inequalities.

Short-fallow rotations on sloping land, with their enhancement of erosion, can be abandoned under the proposed program. Fewer cash and food constraints allow farmers to develop more intensive cultivation with some use of external inputs. When practised on the new terraces they should not increase erosion. However, results suggest that continuous intensive maize cultivation would also take place on the remaining sloping land, creating more problems for lowlanders than the previous rotations. The net balance in terms of environmental services will therefore depend on the positive impact of increased forested and terraced areas versus the intensification on the remaining sloping land.

Keywords

Farm household modelling, ecosystem services, mathematical programming, landscaping

References


Models for assessing farm-level constraints and opportunities for conservation agriculture: relevance and limits of the method, identified from two case studies

François Affholder1, Damien Jourdain2, Veronique Alary3, Dang Dinh Quang4, Marc Corbeels1

1 CIRAD, UPR SCA, Avenue Agropolis, 34398 Montpellier Cedex, France
2 UMR G-EAU, CIRAD – Asian Institute of Technology, Bangkok, Thailand
3 UMR SELMET ICARDA - 11 th floor - 15G. Radwan Ibn El-Tabib street - GIZA - PO Box 2416 - Cairo - Egypte
4 NOMAFSI, Phu Ho Commune, Phu Tho Province, Viet Nam

Corresponding author: francois.affholder@cirad.fr

Which options of conservation agriculture (CA) cropping systems best fit into a particular farm with its specific set of assets and constraints? Our aim was to understand the potentials and limits of ‘optimisation under multiple constraints’ (OUMC) farm models for assessing CA options that are compatible with the goals and constraints of family farms of the tropics.

Farm-level constraints on the adoption of CA options are seldom assessed using quantitative methods. When farm models are developed using multi-criteria assessment of cropping systems, generally only virtual farm types are considered, such as ‘regional farms’ modelled by considering the average production system of large agricultural regions. Similarly, the models consider only contrasting cropping systems, such as comparing conventional systems with systems incorporating straw mulch, or straw mulch and a cover crop, whereas agronomists often need to discriminate ‘best options’ among large sets of cropping systems options that may differ only slightly, such as through variations in the species used as cover crops or in the sowing date of the cover crop relative to that of the main crop. From a set of case studies, we draw some guidelines about how OUMC can better contribute to the integrated assessment of CA options.

We drew on 2 case studies, one in a mountainous region of Vietnam (involving 2 very different agrarian systems that can be considered as sub-cases; Affholder et al. 2010), and the other in the cerrados of central Brazil (Alary et al. 2010). In each region, we identified 3 or 4 farm types with contrasting capital assets (land and livestock), cropping systems, and labour and cash constraints, which result from the relations of the farm with the market and its labour resources. In both case studies, the aim was to assess whether CA systems would improve revenue and would support cash and labour fluxes within the farm and between the farm and the market.
OUMC models (Hazell and Norton 1986; Janssen and van Ittersum 2007) were built for each farm type, with technical coefficients obtained from surveys and trials. Models were calibrated by adjusting the simulated set of activities to the observed set. The CA options were then introduced.

Several scenarios of the prices of inputs and outputs and of agronomic performance of the CA systems were run to assess the short- and medium-term economic attractiveness of each option and its dependence on changes in the economic environment of the farms and on the uncertainties in agronomic and economic data.

The socioeconomic interest of CA options varied greatly across farm types and options. The ability of the model to discriminate between CA options also varied greatly among cases. On all farms, model calibration was robust; i.e. it was possible to obtain a clear correspondence between observed and simulated farm plans, using consistent model parameters. For several simulated farm types, the simulations’ rejection or adoption of CA systems was also robust; i.e. model solutions remained stable over intervals of model parameters that were of the same order of magnitude as the confidence intervals of the main technical coefficients of the model. However, for several other farm types, the simulation results were highly sensitive to small changes in the technical coefficients, especially those describing the agronomic performance of CA systems (yield, labour and input requirements). No obvious farm feature could be identified as determining the robustness of simulations. However, the results suggest that even when the model fails to directly provide a robust answer to the question of the ‘adoptability’ of a given CA option on a given farm, the modelling process and the sensitivity of the model to the key technical coefficients both improve our understanding of the main drivers of farm strategic choices. That can be of great help for further analysing, by other means than mathematical modelling, the relevance of CA options for a given farm.

Keywords

Bioeconomic modelling, family farms

References


Portfolio 3. Conservation agriculture and DMC, an agriculture for the future

Conservation Agriculture is a sustainable development approach designed to reconcile agricultural production with environmental protection. The objective is to produce more and better while also protecting the soil, which is the greatest reservoir of biodiversity on Earth. Such an agricultural model calls for alternative ways of managing land and natural resources. Direct sowing mulch-based cropping systems (DMC) is part of conservation agriculture. The permanent protection of the soil surface thus distinguishes DMC systems from most of the techniques commonly known as conservation agriculture. These cropping systems were inspired by the nutrient cycling in forests, with (1) a high and continuous production of above and belowground biomass, even in poor soils, through the use of a large diversity of plants enhancing various ecosystem services (i.e., soil protection; recycling water and nutrients, exploring a large volume of soil, restructuring the soil), (2) keeping the soil permanently covered, maintaining through the litter system a continuous flow of soil organic matter (SOM) enhancing the dynamics of water and nutrients, and (3) sustaining as an energy source the biological regulation by macro and microorganisms able to perform various functions (i.e., bioturbation, chemical transformation, aggregation, biological nitrogen fixation). Thanks to their deep and branched root systems, trees can take up nutrients from the soil and recycle them in their aerial organs. Conceptualized and tested by the French agronomists Lucien Séguy and Serge Bouzinac (301) based on research initially undertaken in Brazil, DMC systems reproduce the functioning of forest-based ecosystems.

301 – Cameroon
Lucien Séguy, the French agronomist whose research led to DMC concepts

Three simultaneous principles

DMC systems are based on 3 fundamental principles inextricably linked to each other:
1/ Soil is permanently protected by a plant cover -living cover or mulch (302) ;
2/ Soil is neither ploughed nor even superficially tilled. Sowing is done directly through the plant cover, which is mechanically or chemically controlled beforehand (303) ;
3/ Biodiversity is enhanced by implementing rotations, successions and associations with cover plants (304).
302a – Laos
Rice bean on a mulch of *Brachiaria ruzi*

O. Balarabé, Cameroon, 10/2006

302b – Laos
Vigna on a mulch of *Brachiaria ruzi*

H. Tran Quoc, Xayaburi, 2008

302c – Laos
Soybean on a mulch of *Brachiaria ruzi*

H. Tran Quoc, Xayaburi, 2007

302d – Cameroon
Cotton on a soil protected by mulch

O. Balarabé, Cameroon, 10/2006

302e – Laos
Vigna on a cover of *Brachiaria ruzi*

H. Tran Quoc, Xayaburi, 06/2008

302f – Laos
Soybean on rice straw

P. Lienhard, Xieng Khouang, 06/2007

302g – Laos
Vigna intercropped with maize

F. Tivet, Xayaburi, 09/2007
303a – Laos
Mechanical rolling of a *Stylosanthes guianensis* cover using an angle roller

H. Tran Quoc, Xayaburi, 21/04/2008

303c – Guadeloupe
Motorized rolling of a *Crotalaria spectabilis* and *Centrosema pascorum* mixture

H. Tran Quoc, Guadeloupe, 09/2011

303d – Madagascar
A straw mulch ready for direct seeding

A. Chabanne, Lac Alaotra, 2001

303b – Laos
Angle-roller to make mulch before sowing


303e – Laos
Direct seeding into mulch with a bamboo stick

H. Tran Quoc, Xayaburi, 04/2007

303f – Laos
Direct seeding into a cover of weeds with a hand seeder

F. Tivet, Xayaburi, 06/2008
303g - Martinique
Motorized direct seeding of *Centrosema* into a mulch of *Brachiaria*

![Image](image1.jpg)

H. Tran Quoc, Martinique, 12/07/2011

303h - Laos
Demonstration of a motorized seeder for direct seeding

![Image](image2.jpg)

H. Tran Quoc, Xayaburi, 03/2006

303i - Laos
Direct seeding with a mechanized seeder

![Image](image3.jpg)

H. Tran Quoc, Laos, 05/2008

303j - Laos
2 l seeder for motor-cultivator

![Image](image4.jpg)

F. Jullien, Xayaburi, 04/2006

303k – Laos
Direct seeding of maize into mulch using a motor

![Image](image5.jpg)

H. Tran Quoc, Xayaburi, 04/2008

303l - Guadeloupe
Mechanized direct seeding of rice into a mixed cover

![Image](image6.jpg)

H. Tran Quoc, Guadeloupe, 03/2011
Conservation Agriculture and Sustainable Upland Livelihoods

303m - Madagascar
Vigna sprouting out of a cover of cereal straw

303o - Laos
Emergence of soybean through mulch

303p – Madagascar
Vigna emerging from a cover of cereal straw

303q - Laos
Rice sprouting out of a mulch of Brachiaria ruzi

303r – Madagascar
Vigna sprouting out of a mulch

303s - Laos
Vigna sprouting out of a mulch of Job’s tears
304a – Laos
Maize sown on a living cover of *Arachis pintoi*

H. Tran Quoc, Xayaburi, 06/2007

304b – Laos
Rice bean associated with maize as a relay crop

H. Tran Quoc, Xayaburi, 09/2007

304c – Laos
*Stylosanthes guianensis* sown as a relay crop for maize

L. Séguy, Xieng Khouang, 10/2007

304d – Vietnam
Cassava associated with *Stylosanthes guianensis*

D. Hauswirth, Moc Chau, 08/2011

304e – Vietnam
Cowpea associated with *Stylosanthes guianensis* (left); maize associated with a Vigna (right)

D. Hauswirth, Moc Chau, 08/2011

304f – Cameroon
2 years rotation (1 crop /year) between an association *Sorghum / Crotalaria* (background) and a cotton on residues (foreground)

O. Balarabé, North-Cameroon, 08/2006
Chapter 3

Synergizing Conservation Agriculture and Agroforestry

Vietnam
Diversification scheme with upland rice cultivated in tea interrows

Pham Thi Sen, Son La, 07/2011
Buffering soil water supply to crops by hydraulic equilibration in conservation agriculture with deep-rooted trees: application of a process-based tree–soil–crop simulation model to parkland agroforestry in Burkina Faso

Meine van Noordwijk*1, Rachmat Mulia1, Jules Bayala2

1 World Agroforestry Centre, ICRAF Southeast Asia, Bogor, Indonesia
2 World Agroforestry Centre, ICRAF West and Central Africa, Bamako, Mali

*Corresponding author: m.vannoordwijk@cgiar.org

Farmers deal with risks such as weather, pests, diseases, costs of inputs, market prices of products, (family) labour availability, policies regulating land use and, in some contexts, open interpersonal conflict. Perennial components of agricultural systems, especially trees, provide buffer and filter functions that modify, and generally reduce, the farmers’ sensitivity to such external variables. Maintaining a diversity of activities is a time-tested approach to reducing risks (van Noordwijk et al. 1994). The inclusion of trees that provide annual harvests of fruits or long-term high-value timber can reduce risk, even if the trade-off in resource capture is essentially neutral (Santos-Martin and van Noordwijk 2011). Trees shelter farmers from climate variability and assist in adaptation to longer-term trends (van Noordwijk et al. 2011a).

There is a need to assess how to optimise the net balance of tree–crop interactions in ‘conservation agriculture with trees’ (CAWT) systems under variable conditions. Process-based simulation models can quantify the buffering of soil water as a major factor in the climate sensitivity of cropping systems. Examples include research in West African parklands where the redistribution of water from deeper soil layers can partially offset the negative effects of shading (Bayala et al. 2008). Above-ground interactions between trees and crops have positive and negative components: shelter from wind assists crops, especially in the establishment phase, but shading reduces light capture. Below-ground effects (van Noordwijk et al. 2004) are highly complex, with competition and facilitation effects on water and nutrient capture, as well as positive and negative interactions with soil biota.

The combination of above-ground and below-ground tree–crop interactions on the soil water balance is of specific relevance in climates where rainfall in the early part of the growing season is uncertain (and thus positive effects on infiltration and shelter from wind help), while crop growth may exhaust available soil water in the top layers towards the end of the growing season.
The presence of deep-rooted components in the cropping system can, under such circumstances, provide relevant buffer functions by the process of hydraulic equilibration (Bayala et al. 2008). The balance of positive and negative effects may thus shift during the crop growing season (Fig. 1), while crop phenology and harvest index (harvestable biomass / total biomass) vary with distance from the trees.

Because the timing and amount of rainfall vary from year to year and the net effect of trees on soil structure takes time as they gradually increase in size and rooting depth, it is not easy to evaluate the full spectrum of the net effect of trees in CAWT. Simulation models, such as the Water, Nutrient and Light Capture in Agroforestry Systems (WaNuLCAS) model (van Noordwijk et al. 2011 b), can help.

WaNuLCAS consists of a core set of resource capture modules and a set of additional modules to deal with specific additional effects (Fig. 2).

We developed WaNuLCAS applications for parkland agroforestry in Burkina Faso, the study site of Bayala et al. (2008).

The parameterisation of tree and crop variables at the site is incomplete, but the model can provide response functions over rainfall gradients for trees with various rooting patterns, with or without effects on hydraulic redistribution. An initially surprising result of comparisons of runs with and without hydraulic equilibration is that the effects on predicted tree performance exceed effects on crop growth, leading to more intense shading and negative overall effects on crop growth in many situations. As hydraulic equilibration depends on the presence of roots as conductors but not on active uptake, details of tree phenology have a large effect; and trees that drop their leaves during the crop growing season, such as *Faidherbia albida*, favour crop growth and yield.

Differential effects on crop harvest index with increasing distance from the tree stem reflect details of the way each individual rainy season unfolds. In some years there is not enough recharge of groundwater for hydraulic equilibration to function, but in other years late rains make the crop less dependent on such equilibration.

Ongoing analysis of the oxygen isotope signature of rainfall, groundwater and tree stem flow at the site will allow a more detailed test of model validity in the near future. Use of a dynamic root growth module along the lines of Mulia et al. (2010) will help to identify the specific clues to look for in climate change predictions if we want to evaluate the use of trees to reduce human vulnerability.

**Keywords**

Africa, agroforestry, climate variability, conservation agriculture with trees, WaNuLCAS
Figure 1. Schematic representation of positive (+) and negative (−) tree–crop (t/c) interactions during a growing season, based on effects on infiltration, hydraulic redistribution, shading, crop phenology and harvest index.

Figure 2. Core and additional modules that relate inputs to outputs in version 4 of the WaNuLCAS model (van Noordwijk et al. 2011b).
References


Conservation agriculture with trees in sub-Saharan Africa: case studies from four countries

Jeremias G. Mowo*1, Jonathan Muriuki1 and Saidi Mkomwa2

1 World Agroforestry Centre (ICRAF), Box 30677 – 00100, Nairobi, Kenya
2 African Conservation Tillage Network

*Corresponding author: j.mowo@cgiar.org

Conservation agriculture (CA) and agroforestry are promoted as practices that can reverse the poor performance of the agricultural sector in sub-Saharan Africa (SSA), where the gap between population growth and agricultural production is increasing. To avert large-scale hunger, food production must double by 2030 (ACT 2008), a target that is hardly feasible under the current land management practices largely characterized by maximum soil disturbance, low use of inputs, monocropping and deforestation. For example, fertilizer consumption in SSA is 6 kg/ha (Smaling et al. 2006), compared with the current world average of 100 kg/ha. Poor agricultural practices have led to nutrient mining, soil erosion and declining soil organic matter.

In response to this scenario, the African Union Ministers of Agriculture, Land and Livestock meeting in Addis Ababa in 2009 declared support for the imperative of scaling up CA and agroforestry across the continent. CA combines the simultaneous principles of reduced tillage or zero tillage, soil surface cover and crop rotations or associations, and aims at achieving sustained production levels while conserving the natural resource base (Bayala et al. 2011). Agroforestry refers to land-use systems and technologies in which trees and shrubs are grown in association with crops or livestock in a spatial arrangement, a rotation or both. Agroforestry helps in enhancing the conservation of biodiversity, adapting to and mitigating climate change, achieving food security and reducing rural poverty by increasing soil fertility and crop and livestock yields. CA and agroforestry can therefore provide a practical and sustainable solution to the poor performance of agriculture in SSA (Garrity et al. 2010), where the majority of smallholder farmers cannot afford costly inputs. Yet the benefits of CA and agroforestry notwithstanding, their uptake in Africa is disappointingly low. The two practices have commonly been promoted individually and at times under different institutional settings. The World Agroforestry Centre therefore hypothesised that adopting a tree-based CA strategy, called Conservation Agriculture with Trees (CAWT), would combine the best of each component and hence stimulate their adoption. The role of trees in promoting CA is best illustrated through their role in protecting soil, which is normally difficult in SSA given the multiple uses of crop residues (fodder, fuel, construction). Trees provide year-round soil cover and hence release crop residues for other uses.
Effective scaling up of CAWT in Africa requires a solid knowledge and partnership base. We need to know where and when trees can contribute to CA principles, and need the institutional and policy setup necessary for enhancing CAWT adoption. This paper is an attempt to fill the knowledge gap by establishing the extent of and factors affecting adoption of CA and agroforestry in order to derive a comprehensive strategy for combined scaling up of both under CAWT. The study was guided by 3 research questions: What is the extent of adoption of CA and agroforestry by smallholder farmers in SSA? What are the policies and institutional factors promoting or hindering large-scale adoption of CA and agroforestry? What is the institutional and organisational infrastructure required to support scaling up of CAWT?

The study was conducted during 2011 and 2012 in 4 countries in SSA -Zambia (southern Africa), Kenya, Tanzania (east Africa) and Ghana (west Africa)- where there was strong evidence of scaling up of CA. A rapid appraisal by the Africa Conservation Agriculture Tillage Network and FAO between February and April 2009 showed Zambia to have the largest area under CA (120 000 ha), followed by Ghana (30 000 ha), Kenya (15 000 ha) and Tanzania (10 000 ha). Of the 4 countries, Zambia has advanced in integrating trees in CA: 100 000 farmers already practise CAWT. Community- and farm-level surveys assessed the extent of adoption of CA and agroforestry by smallholder farmers, policy and institutional factors influencing scaling up of CA and agroforestry, and opportunities for policy reforms and institutional strengthening in support of scaling up CAWT. The factors assessed were biophysical and socioeconomic measures, tenure security, capital endowment, extent of use of CA and agroforestry innovations, and policy and institutional factors influencing adoption. Successful policy reforms, such as fertilizer subsidies, seeds and provision of CA tools for farmers practising CA, were analysed to derive key lessons. Qualitative data were analysed using explorative methods (descriptive, correlation and non-parametric), while logistic regression analysis was used to estimate the extent and factors of adoption of CAWT at farm level.

The adoption of CA is still very low and slow in the 4 study countries, with <5% of smallholder farmers adopting all 3 components of CA (minimum tillage, adequate soil cover, and crop rotations or associations). More common is the adoption of 1 or 2 components. Factors influencing the adoption of CA included age of the household head, household size, access to training resources, access to information and knowledge, and farmers’ perception of CA as potentially mitigating climate change. Older farmers were found to be less receptive to new ideas and risk averse. Household size (as a proxy for labour availability) was positively correlated with adoption. Thus, CA may not be adopted as a one-size-fits-all intervention, so interventions need to be targeted to specific local conditions.

Agroforestry is fairly well supported by farmers, especially in Kenya, Tanzania and Zambia, where on average 51% of farmers intercrop trees with crops (compared with 25% in Ghana).
Farmers cited fuel wood, timber or poles, shade, windbreaks, fruit, fodder, mulch, soil erosion control and apiculture as factors motivating them to adopt agroforestry. Reasons given for non-adoption include the long period needed for trees to mature, competition with crops, lack of germplasm, lack of knowledge on management of trees, and land tenure.

National policy frameworks in the study countries show that CAWT can be scaled up under a number of existing policies related to sustainable land and water management. However, there is a low level of awareness of CAWT practices, and there is poor coordination among the various actors and stakeholders (except in Zambia). The results suggest that there is need for formal institutional frameworks to incorporate existing local institutions in the efforts to scale up adoption of CAWT.

CAWT should be seen as a concept beyond agriculture and needs to be promoted as a theme, ensuring effective linkages between R&D activities. There is need for further research into how CAWT can be packaged and targeted so as to reach large numbers of farmers.

**Keywords**

Agroforestry, soil fertility, ecosystem resilience, climate change

**References**


**Bibliography**

Potential tree-crop combinations for conservation agriculture with trees in Vietnam

Hoang Thi Lua*, Tran Nam Thang, Nguyen Quoc Binh, Tran Van Hung, Giang Thị Thanh and Delia C. Catacutan*

1 World Agroforestry Centre (ICRAF), Vietnam  
2 Hue University of Agriculture and Forestry, Vietnam  
3 Nong Lam University, Ho Chi Minh City, Vietnam  
4 NOMAFSI, Phu Tho, Vietnam  
5 Tay Nguyen University, Vietnam

*Corresponding author: hlua@cgiar.org, D.C.Catacutan@cgiar.org

In Vietnam, evidence of environmental harm caused by conventional (intensive) agriculture with the recent extension of monocropping has been reported (Curtis 2012; Wood et al. 2006). At the same time, agricultural production is required to increase further. Conservation agriculture (CA) and agroforestry practices have high potential to improve farm productivity and profitability. However, scaling up of CA remains a major challenge for small-scale farmers, and agroforestry approaches to maintaining soil fertility have met with limited success, especially where poverty and hunger force farmers to use desperate, short-term survival strategies that take precedence over longer-term sustainability.

CA and agroforestry have often been viewed as independent approaches. Scientists at ICRAF are working on ‘conservation agriculture with trees’ (CAWT), an approach that would add to a fourth principle to CA -that of tree-crop integration- and meet the short-term needs of small-scale farmers for food and income, while contributing towards sustainable resource management.

Maximising the synergic effects of trees and crops requires knowledge of selecting species combinations and of good management of trees and crops, such as increasing the supply of nutrients to the crop, supplying N from tree roots to crop roots, long-term effects on erosion, soil organic matter content and soil compaction (van Noordwijk et al. 2011), and minimising the competition between them. In reality, the empirical assessment of tree-crop combinations is laborious, costly and time consuming. The use of modelling tools, such as WaNuLCAS (Water, Nutrient and Light Capture in Agroforestry Systems; van Noordwijk and Lusiana 1999), provides a good starting point, as it can simulate tree-crop interactions in agroforestry. WaNuLCAS is based on the above- and below-ground architecture of trees and crops, elementary tree and crop physiology and soil science. It can be used to assess the profitability and sustainability of various agroforestry systems.
To assess the potential agroforestry systems that can complement CA practices in Vietnam, a collaborative study was implemented with partners in three universities in Vietnam, namely Hue University, Tay Nguyen University and Nong Lam University, as well as the Northern Mountainous Agriculture and Forestry Science Institute (NOMAFSI). We used WaNuLCAS to compare potential agroforestry systems that can complement CA in Vietnam, assessing carbon stocks, yields and greenhouse gas (GHG) emissions. We compared 3 systems: intercropping cassava (*Manihot esculenta*) in an *Acacia mangium* plantation in the first year of establishment in Phu Tho province; intercropping cassava and groundnut in a rubber plantation in Hue province; and intercropping cassava in a *Litsea glutinosa* plantation in Gia Lai province. These tree and crop components are commonly planted by farmers, and give good economic returns and environmental protection. Data used in the WaNuLCAS model were parameterised from and calibrated against existing practices. The model can simulate different management options based on spacing, fertilisation, irrigation practices and pruning regimes.

During the first 2 years, integrating cassava into rubber could improve the economic effectiveness (through cassava sales), accumulate more carbon, reduce GHG emissions ($N_2O$, $NH_3$) and provide cash benefits to farmers. Intercropping rubber with cassava or groundnut in the third year is less viable because of above-ground competition between trees and crop.

Farmers who intercrop *Litsea* and cassava usually plant cassava every 2 years in the first 4 years, yet the simulation showed that they can intercrop it every year without adversely affecting the growth of *Litsea*. Farmers who continue to intercrop cassava in the first 4 years will thereby increase their income. The economic and environmental benefits of the system would increase when CA practices such as mulching are included (cassava residues can be left on the soil surface), and further still with the use of inorganic fertiliser.

At the current planting density of 3 m x 2 m, acacia produces the highest biomass in the second year (2.5 kg/m²). When the trees and cassava are spaced at 5 m x 2 m, the total biomass of the system is 5 kg/m², although the biomass of acacia is only 1.8 kg/m². Intercropping cassava with acacia is optimal only in the first 2 years.

Although we did not consider monocrop systems, we posit that integrating trees with crops has greater and multiple system benefits, which can be enhanced when combined with CA practices. We therefore recommend CAWT to achieve higher economic returns and environmental protection in Phu Tho, Hue and Gia Lai provinces, Vietnam.

**Keywords**

Agroforestry, WaNuLCAS, CAWT, ICRAF
References


Bibliography


Improving productivity and services of trees in slash-and-burn systems. What lessons from assisted natural regeneration in DR Congo can be applied to other humid tropical regions?

Régis Peltier*1, Simon Diowo2, Baptiste Marquant3, Morgan Gigaud4, Adrien Peroches5, Pierre Clinquart2, Pierre Proces5, Emilien Dubiez2, Cédric Vermeulen5 and Jean-Noël Marien1

1 CIRAD, UPR BSEF, International Campus Baillarguet, 34398 Montpellier Cedex 5, France
2 Projet Makala, 57 Avenue des Sénégalais, Kinshasa-Gombé, R. D. Congo
3 AgroParisTech, 648 rue Jean-François Breton, Domaine de Lavalette, BP 44494, 34093 Montpellier Cedex 5, France
4 Université d’Orléans, Master 2 Biologie, option écosystèmes terrestres, 45000 Orléans, France
5 ULG/ Agro-Bio-Tech, Gembloux, Belgium

*Corresponding author: regis.peltier@cirad.fr

In the tropics, slash-and-burn (S&B) cultivation is often considered to cause the destruction of forests and wooded savannahs, loss of biodiversity, lack of fuelwood, rarefaction of timber and non-timber forest products, decline of soil fertility and erosion (de Wasseige et al. 2012).

Many researchers and development workers have sought alternatives to traditional S&B. Unfortunately, they have had limited success, especially in tropical mountain regions. Indeed, it is not easy for very poor farmers to switch from extensive systems where labour is the major input to intensive systems that require other inputs. Therefore, the CIRAD Makala project was carried out in the Democratic Republic of Congo (DRC) to improve the S&B system, rather than replace it.

Assisted natural regeneration (ANR) of rainforests has been used in the Sahel for over 20 years (Montagne 1996; Larwanou et al. 2006). It has allowed the development of complex agroforestry systems on hundreds of thousands of hectares in Niger and northern Cameroon. Since 2009, it has been implemented in the humid tropics, where large-scale S&B clears forests for cropping, which is followed by species-poor Chromolaena odorata or Imperata cylindrica pasture.

On the Bateke Plateau in DRC, the Makala project is involving the local population in testing ANR methods in the last remnants of gallery forests. Through a participatory method (Marie et al. 2009), 60 farmers in 4 villages are assessing the potential of timber plots. When farmers want to cultivate a patch of forest, they examine the potential benefits from the trees, such as in improving soil nutrition or producing edible caterpillars, fruits, firewood, timber or medicines. Then they select trees to retain while avoiding excessive shading, and mark the trees with a ring of paint.
The unmarked trees are felled and sawn or cut to produce charcoal. The felling damage and the passage of fire reduce the tree density to about 60/ha. The plot is then planted to cereals (e.g. maize) and cassava. During crop growth, the farmer selects tree seedlings, shoots or suckers to keep. These trees develop after the cassava harvest during the fallow cycle (6-12 years). During this period, the land is reserved for gathering, grazing, hunting and beekeeping.

After 2 years of ANR, trees were inventoried on 300 plots to characterize the state of unimproved fallows and on 23 ANR plots for comparison. Surveys were conducted with farmers who had used the ANR method and those who had not (Peltier et al. 2011).

The biomass of the unimproved fallows was 95% lower than the average biomass of natural forests in the Congo Basin. The ANR method allowed farmers to keep about 1000 saplings of 20 species per hectare while growing crops. The young trees grew an average of 1 m per year, and exceeded the size of invasive shrubs before the cassava harvest and the abandonment of cultivation. Subsequent shading reduced the development of vegetation, fire hazards and the encroachment of savannah at the expense of forest.

ANR facilitates the progressive establishment of agroforestry. This system, inspired by ancient practices but adapted to the opportunities and needs of today's farmers, improves soils and biodiversity while increasing the peoples' resources. Farmers are being encouraged to continue this effort beyond the current project. One of the alternatives being explored is that of a forest fund, as exists in Europe, funded through carbon credits and through reducing emissions from deforestation and forest degradation. This method could also be used in other environments, such as the mountains of South-East Asia.

**Keywords**

Improved fallow, biomass, biodiversity

**References**

Participation of farmers in temperate fruit development in the north-western highlands of Vietnam

Pham Thi Vuong¹, Nguyen Van Chi¹, Tran Van Dat¹, Pham Van Ben*¹

¹ Plant Protection Research Institute, Dong Ngac commune, Tu Liem district, Hanoi, Vietnam

*Corresponding author: benkhoahoc@yahoo.com.vn

Many temperate fruits, including apple, plum, peach and apricot, are being grown in the north-western highlands of Vietnam, in Son La, Lai Chau and Lao Cai provinces. These fruits are grown by ethnic minorities who used to grow poor-quality, low-yield cultivars using traditional practices without pruning or pest management (Minas and Edward 1999). An ACIAR project (‘Improved market engagement for sustainable upland production systems in the north west highlands of Vietnam’) was devised to increase farmers’ engagement in competitive value chains while improving land and crop management practices in order to develop sustainable and profitable farming systems. Identifying new cultivars and modernising traditional production practices in temperate fruit production offer the chance to improve the economic and living conditions of these ethnic groups and to fight poverty.

We used participatory rural assessment (Adebo 2000) to help farmers identify potential innovations and changes to current practices to achieve sustainable development. Their participation in the research and assessment helps farmers improve their understanding of their socioeconomic and ecological conditions and the constraints and opportunities in their communities, and to establish collaborative relationships. The farmers identified potential crops and production practices that would improve productivity and quality. A rapid value-chain appraisal of temperate fruits in Moc Chau district, Son La province, identified opportunities for improved and diversified peach and plum value chains. New cultivars and better crop management such as pruning and pest control would allow the farmers to produce more, better-quality peaches for market.

To convince farmers to accept new cultivars and change their practices, we introduced new peach cultivar ĐCS1 to a number of smallholders to compare its economics with those of other local peach cultivars and temperate fruits. Most local peach cultivars have small fruits and a very short harvest season. Their later harvest time than that of ĐCS1 exposes them to fruit fly damage, which brings a low price, made worse by competition with other temperate fruits such as plum. Advanced management practices including pruning (McEachern et al. 1996) and pest management (Berger et al. 2006) have been introduced to improve productivity and quality.

Fifteen smallholders in Lai Chau province planted ĐCS1.
It has grown very well and began fruiting only 15 months after planting, compared with 36 months for local cultivars. Tree height ranged from 165 to 173 cm, trunk diameter from 3.7 to 4.1 cm and canopy diameter from 98 to 176 cm. Its 2- to 3-week earlier harvest time reduced fruit fly attack, which allowed a good sale price.

Farmers and the Lai Chau agriculture department praised the results of the project. Many farmers have planted project peach trees and are now waiting for them to grow. This is an important success of the project. The project has changed traditional practices by introducing pruning methods that increase quality and productivity. In addition, farmers have been encouraged to intercrop their newly planted orchards with pumpkin, peanut or maize to reduce erosion (Banda et al. 1994) (Fig. 1).

In the next phase we will extend the peach plantings to 300 ha. Two hundred farmers and agricultural staff have been trained and have contributed to the success of the project. Support for farmers in participatory research and extension for temperate fruit development will achieve sustainable development in the north-western highlands of Vietnam.

Pictures 1 and 2. Temperate fruit trees intercropped with peanut and maize.

Keywords

Participatory rural assessment, rapid value chain appraisal, peach, quality, productivity, Lai Chau

References


Cultural methods for improving production of Tam Hoa plums in Son La, Vietnam

Nguyen Thi Thuy*¹, Pham Thi Vuong¹, Le Duc Khanh¹, Nguyen Nam Hai¹, Do Xuan Dat¹, Nguyen Van Chi¹, Nguyen Thi Thanh Hien¹

¹Plant Protection Research Institute (PPRI), Dong Ngac, Tu Liem, Hanoi, Vietnam

*Corresponding author: thuyppri@yahoo.com

Since the early 1990s, the production of temperate fruits, especially ‘Tam Hoa’ plum (Prunus salicina), has played an important role in generating income for the people of the mountainous Moc Chau region of Son La province, Vietnam. Its extension was driven spontaneously by farmers. Income from Tam Hoa plum production now accounts for 40% to 75% of household gross income (PPRI 2009). However, production is limited by spontaneity of orchard establishment, low application rates of fertilisers, lack of pesticide use and absence of pruning (PPRI 2009).

In 2009, ACIAR funded the ‘Improved market engagement for sustainable upland production systems in the north west highlands of Vietnam’ project with the aims of developing a market-driven farming system that would use cultural methods to increase the yield and quality of Tam Hoa plums; increasing income, especially that of minority groups; and contributing to poverty alleviation by developing knowledge of orchard management. Activities focus on canopy management (pruning), plant nutrition, IPM, orchard floor management, and harvest and postharvest optimisation.

We conducted an experiment with the aim of improving the quality and yield of Tam Hoa plums. The experiment was based on the results of an investigation to characterise production and marketing practices within socioeconomic, ethnic and gender-specific contexts. The experiment was designed through a participatory approach to economic and feasibility analyses of the cultivation practices. This approach ensured that the practices developed were suitable for the farmers, the current production practices and the socioeconomic conditions.

Field experiments were conducted in 2010 and 2011 in 5 orchards aged 4 to 6 years old at Pieng Sang village, Phiang Luong commune, Moc Chau district. Farmers’ practices (T0) were compared with 2 treatments: pruning + fertiliser (20 kg manure, 280 g N, 13 g P and 160 g K/tree) + mulching (straw and grass) (T1); and pruning + mulching (T2).

In 2010, T1 (11.9 kg/tree) and T2 (8.1 kg/tree) had significantly higher yields and larger fruits than T0 (2.06 kg/tree; P = 0.05), although there was no significant difference between T1 and T2. Fruits in T1 and T2 were significantly softer than in T0, without significant differences between T1 and T2 (Table 1). There were no significant differences in the content of soluble solids (predominantly sugars).
In 2011, pheromone traps and food traps were set up to monitor the emergence and composition of fruit flies. The results were then used to assess yield, fruit quality and the economic effects of pruning, fertiliser, pesticides and mulching.

In 2011, fertiliser application increased plum yield (T1, 16.47 kg/tree; T2, 9.11 kg/tree; T0, 5.63 kg/tree) and achieved a higher rate of fruits heavier than 30 g (up to 45.8%) than pruning (23.3%) and T0 (17.1%). The yield and size of fruits were not significantly different between T0 and T2. Fertiliser and pruning did not affect firmness but somehow reduced the soluble solids content (Table 1). Fruit fly control reduced the rate of damage (7%–16%) below that in T0 (32%) (Table 2).

Table 1. Fruit quality indexes, Pieng Sang, 2010.

<table>
<thead>
<tr>
<th>Indexes</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
<td>T2</td>
</tr>
<tr>
<td>Brix</td>
<td>11.24a</td>
<td>11.13a</td>
</tr>
<tr>
<td>Firmness (kg/cm²)</td>
<td>7.64a</td>
<td>7.59a</td>
</tr>
</tbody>
</table>

T0, farmer practice; T1, pruning + fertiliser + mulching; T2, pruning + mulching.

Table 2. Fruit fly control, Phieng Sang, 2011.

<table>
<thead>
<tr>
<th>Time</th>
<th>Fruit stage</th>
<th>Rate of damage (%)</th>
<th>Farm 1</th>
<th>Farms 2, 3</th>
<th>Farms 4, 5</th>
<th>Farmer practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 May</td>
<td>Started to change colour</td>
<td>3.48</td>
<td>5.22</td>
<td>4.35</td>
<td>4.35</td>
<td></td>
</tr>
<tr>
<td>4 June</td>
<td>Physiologically ripe</td>
<td>7.0</td>
<td>8.0</td>
<td>8.0</td>
<td>11.0</td>
<td></td>
</tr>
<tr>
<td>22 June</td>
<td>Fully ripe</td>
<td>9.0</td>
<td>7.0</td>
<td>16.0</td>
<td>32.0</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Estimated yield of plums in Pieng Sang, 2010–2011.
These results show that pruning combined with fertiliser application (3 times) and mulching improved fruit quality while increasing yields threefold to fivefold. In the north-western highlands of Vietnam, where the weather is cold and foggy and there is little rain from November to February, mulching retains soil moisture while increasing the efficiency of fertilisers (CIRAD-FLHOR, PPRI 2011). In the rainy season, mulching can also prevent erosion (CIRAD-FLHOR, PPRI 2011).

**Keywords**

Mulching, participatory approach, pruning, pheromone traps

**References**


Le DK, Tran TT, Dang DT. 2004. Study the integrated technical methods to develop the temperate fruit plants (plum, persimmon and peach) that have a high quality in the montane provinces in Northern Vietnam. National independent project. Code: ĐTDL 2004/09.


PPRI. 2009. The survey results of the site selection in Son La

Portfolio 4. DMC systems can be adjusted to local conditions

DMC systems can be designed for any commonly cultivated commercial variety. It is also possible to use alternative varieties specifically selected to optimize the efficiency of DMC systems.

For instance, this is the case of SEBOTA poly-aptitude rices, which were created by Lucien Séguy, Serge Bouzinac and Jacques Taillebois in order to provide high yields even when facing severe agro-climatic risks: rice fields with poor water control, crops under rainfed conditions, etc. (309).

DMC systems with combined food and forage production can also be designed for better integration of agriculture and livestock (310).

Conservation agriculture is not limited to annual crops. It can also be used to design resilient and productive tree crop-based systems. For instance, multi-storey and diversified plantations on living covers facilitate integrated pest management (311).

All these cropping systems allow an intensification of agricultural production with minimum environmental impact. This is called “sustainable intensification”.

Conservation Agriculture and Sustainable Upland Livelihoods
309a (left) and 309f (right) – Laos
Grains of a SEBOTA rice just before harvest

309d (left) and 309h (right) – Laos
Collection of high-yielding SEBOTA rice under rainfed conditions

309g (left) and 309b (right) – Laos
Harvest of a SEBOTA rice variety

309c (left) and 309e (right) – Laos
Grains of a SEBOTA rice just before harvest
310a - Laos
Maize and pigeon pea. Pigeon pea grains are used to improve protein inputs for pigs

Bouamlao Paklay - H. Tran Quoc, Xayaburi, 06/2007

310b Laos
Direct seeding of *Brachiaria ruziziensis* to improve fodder resources available for cattle

P. Lienhard, Xieng Khouang, 06/2007

310c Vietnam
Tea with *Arachis pintoi* (N-fixing cover plant with prospective use for early identification of nutrient deficiencies on tea).

Dang Van Thu, Phu Tho, 04/2012

311f – Guadeloupe
Banana plantation combined with a cover of *Stylosanthes guianensis*

H. Tran Quoc, Guadeloupe, 07/2011

311g - Guadeloupe
Banana plantation combined with a cover of *Centrosema pascorum*

H. Tran Quoc, Guadeloupe, 09/2011
311b – Vietnam
Establishment of a living cover of pinto peanuts in tea interrows

311a - Vietnam
Diversification scheme with upland rice cultivated in tea interrows, thus securing farm income

311c - Vietnam
Diversification scheme with cowpea grown in coffee interrows during early stage of coffee plantation

311d - Vietnam
Tea plantation (commercial stage) on a living cover of pinto peanuts

311e - Vietnam
Mixed plantation of tea, arabica coffee and rubber. In the first year, maize associated with *Arachis pintoi* is grown in interrows of tree crops.
311i, 311j – Cambodia
Mixed plantation of rubber and *Dalbergia bariensis* (endangered species with a high value wood), 58 months after planting

311h - Cambodia
Mixed plantation of rubber trees and *Hopea odorata* (high value wood species), 58 months after planting

311k – Cambodia
Planting of a mixed plantation of rubber and *Dalbergia bariensis* on a living cover of *Stylosanthes guianensis*

311l - Cambodia
Mixed plantation of rubber trees and *Afzelia xylocarpa* (high value wood species), 58 months after planting
Chapter 4

Conservation Agriculture and Ecosystem Services

Laos
Cover of finger millet (Eleusine coracana), a plant able to restore soil fertility

A.Chabanne, Laos, 09/2007
Keynote 5: Can conservation farming practices ensure agricultural ecosystem stability?

Neal Menzies*1, Andrew Verrell2, Gunnar Kirchhof1

1 University of Queensland, School of Agriculture and Food Sciences, Brisbane, Qld 4072, Australia. n.menzies@uq.edu.au, g.kirchhof1@uq.edu.au
2 Tamworth Agricultural Institute, NSW Department of Primary Industries, Tamworth, NSW 2340, Australia. andrew.verrell@dpi.nsw.gov.au

*Corresponding author: n.menzies@uq.edu.au

Abstract

Conservation agriculture (CA) is deemed to be the only sustainable modern agricultural production system. Adoption rates in the Americas and Australia have been extremely high, partly because of the increased and more efficient crop production, but primarily because of the reduction of the cost of herbicides, mainly glyphosate, after patents expired. A key component of CA is herbicide use to replace tillage in the control of weeds. Other equally important components are mechanisation and the retention of crop residues. Practitioners of CA universally ‘understand’ that all components must be applied; partial adoption of CA principles is be sustainable. In regions where CA has been adopted, it currently offers the best management practice for agricultural ecosystem sustainability. However, in many developing countries, practice change for all components of CA may not be possible (while in the developed world it may not be entirely beneficial). Access to herbicides is probably a major limiting factor, particularly in many sub-Saharan counties. The need for agricultural mechanisation still limits the adoption of CA in many African and Asian countries. Crop rotation may not fit into traditional production systems, and minimum tillage (MT) is not possible to implement for root or tuber crops. Similarly, the production of genetically modified cotton requires tillage for pest control. Soil and climate interactions may also hinder adoption of MT. Some soils, for example heavy self-mulching Vertosols, respond very well to the conversion from conventional to zero tillage (ZT), and increased water use efficiency (WUE) becomes evident shortly after aggressive tillage operations end. However, less active soils, in particular hard-setting soils, may not respond rapidly to ZT, and it may take several years of ZT practice before soil structure has sufficiently improved for CA to outperform conventional practices. In Australia, profound nutrient stratification (accumulation in the surface soil) also presents a challenge to ZT. At present, it seems that CA is promoted as a ‘must adopt’ system, although this may not be possible in some biophysical or socioeconomic environments. The change to CA needs to be a stepwise process in which adoptable components are promoted and associated limitations are managed without short-term yield sacrifice.
Key indicators of the agroecosystem stability of CA are soil organic matter (OM) build-up and carbon sequestration due to minimum soil disturbance, residue retention and increased WUE. Increases in the soil organic carbon (OC) stocks on CA fields in the Americas are reported. Research in Brazil suggests that OM build-up under CA can even be greater than under natural ecosystems. Results from the USA suggest that soil OM build-up is a major mechanism for carbon sequestration. CA was adopted on Vertosols in Australia partly because of the realisation that carbon stock depletion needs to be arrested and the belief that soil OM can be increased in CA systems. However, despite soil structural improvement due to the adoption of ZT systems, recent data from longitudinal studies shows that carbon stocks have continued to decrease under CA, though at a lower rate than under IA. Unless annual rainfall is above 500 mm, increases in soil OM as a consequence of CA practices appear to be negligible. If these values also apply to soils and climates in Africa, large regions of Africa need to be excluded as potential carbon sinks.

Under MT, WUE will increase once soil structure has improved, even in the absence of OM increases. This is primarily due to the greater amount of actual available water but not necessarily to an increase in potential available water. The main mechanism for high amounts of plant-available water in the soil profile, and associated higher WUE, is greater infiltration rates. Benefits for crops are obvious, but there may be a hidden cost for environmental flows. Higher WUE is synonymous with lower losses in the water balance, and may well lead to reduced water availability downstream of regions where CA is practised. The potential impact on landscape hydrology is largely unknown.

**Keywords**

Conservation agriculture, conventional agriculture, minimum tillage, nutrient stratification, soil organic matter, soil structure
1. Concept of conservation agriculture and adoption

The term conservation agriculture (CA) is often used synonymously with no-tillage (NT) or zero-tillage (ZT) or even minimum tillage (MT). However, practitioners of reduced tillage understand that the practice of NT as defined as planting into an untilled soil using minimum possible soil disturbance is only one component of the practice of CA. Other equally important components are the use of herbicides to control weeds, the maintenance of crop residues and the use of crop rotations to control pests and diseases. Mechanisation, even on a small scale, is almost a prerequisite to CA owing to the inherent difficulties in planting and managing a crop without tillage. FAO (2012) identifies direct planting of crop seeds (continuous minimum mechanical soil disturbance), permanent soil cover with crop residues and cover crops (permanent organic soil cover), and crop diversity (diversification of crop species grown in sequences or associations) as principles of CA.

CA practices have the greatest rates of adoption in the Americas. However, reliable values for the use of CA are ambiguous and are often linked to the use of MT or ZT technology only. Dumanski (2006) reported that ZT accounts for 47% of cropping in South America, 39% in the USA and Canada, and about 3.9% in Europe, Africa and Asia. Including regions where tillage is practised occasionally, Derpsch and Friedrich (2009) report that NT accounts for 70% in Brazil and 90% in the USA. Llewellyn and D’Emden (2010) report a ZT adoption rate of 90% in Australia. This is based on telephone surveys in which ZT was defined as NT ‘including sowing techniques using zero-till with disc machines’.

Except in Europe, factors affecting adoption are linked to the ability to mechanise, access to and expertise in the use of herbicides, and options for crop rotations and sequences.

2. Case study - CA in eastern Australia

Southern Queensland and northern and central New South Wales (NSW), between 26° and 32°S and east of 147°E, lie in the semiarid subtropical to temperate zone. The mean annual rainfall is 476-750 mm, with the distribution changing from summer (October-March) -dominant in the north (70%) to uniform in the south (53%) (Verrell 2004).

The main cropping soils are grey, brown and black Vertosols (Vertisols), red or brown Sodosols (Alfisols), red and brown Chromosols (Alfisols) and red Kandosols (Alfisols, Ultisols) (Verrell 2004).

Both summer and winter crops are grown across the region. The proportion of winter crops, especially wheat and barley, increases from north to south. The main cereal crops are bread and durum wheat, barley, sorghum and maize. Other crops include oilseeds (canola, mustard, sunflower), pulses (chickpea, faba bean, field peas, lupins, mung bean, soybean) and cotton.
Winter crops are often grown after a summer fallow period of 6 months, and summer crops after a winter fallow, to enable water and mineral nutrients to accumulate in the soil profile for use by the following crop. These crops are often rotated for agronomic and economic reasons. When changing from winter to summer crops or vice versa, a longer fallow period of 12-15 months may intervene. Alternatively, a short fallow period of 1-3 months may occur between crops if soil water reserves are replenished sufficiently to allow ‘double cropping’.

2.1. Zero-tillage: the beginning

Soil conservation was the main reason for the development of ZT in the 1970s and ‘80s. A dramatic increase in the area cropped during the 1960s and ’70s, using conventional tillage, had exposed 69% of this area to severe erosion (Junor et al. 1979). Early research by Cummins and Esdaile (1972) suggested that stubble should be retained on the surface and used in strip cropping to reduce surface erosion. Subsequent work by Marston and Doyle (1978) and Donaldson and Marston (1981) advocated its widespread use as a normal cropping practice. This then led to the need for machinery that could handle large amounts of surface crop residues. Teams of researchers and extension officers in Queensland and northern NSW worked for many years trialling and developing machinery (Martin and Felton 1983, 1984, 1985; Silburn and Freebairn 2004). To aid trash flow through the machine at sowing required 2 major developments: wider row spacing of ground-engaging gear and higher clearance of the toolbar from the soil surface. There is now a large range of commercial ZT ground-engaging gear for growers to use.

Maintaining residue cover during the fallow was made possible with the release of glyphosate in the 1970s to supplement diquat and paraquat. Initially, controlling weeds with herbicides was regarded as expensive. However, as the cost of glyphosate decreased, the adoption of chemical weed control increased.

2.2. Importance of fallowing and fallow management to crop production

Rainfall in this region shows a high degree of year-to-year variability. Using mean annual rainfall as a comparison, Nicholls (1997) showed that rainfall in this area was 10% more variable than in similar regions around the world. In terms of spatial variability, Hayman (2001) showed that in 7 major towns in this region, rainfall variability ranged from 2% to 35%. McClymont et al. (2006) used long-term climate records in a daily water balance model based on the distribution of seasonal rainfall to demonstrate the importance of stored fallow water (Table 1).

Winter crops in Dalby derived 62% of total water use from the fallow. Both summer (32%) and winter crops (36%) are equally dependent on fallow stored water in Moree. Winter crops at Walpeup used only 11% of stored water, reflecting the dominance of winter rainfall.
Table 1. Rainfall, fallow efficiency and fallow dependency in 3 locations in eastern Australia (reproduced from Thomas et al. 2007).

<table>
<thead>
<tr>
<th>Latitude</th>
<th>Location</th>
<th>Season</th>
<th>Annual rainfall (mm)</th>
<th>Percentage of annual rain in crop</th>
<th>Fallow efficiency (%)</th>
<th>Fallow dependency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27°11’S</td>
<td>Dalby</td>
<td>winter</td>
<td>641</td>
<td>29</td>
<td>24</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>Dalby</td>
<td>summer</td>
<td>641</td>
<td>59</td>
<td>26</td>
<td>27</td>
</tr>
<tr>
<td>29°28’S</td>
<td>Moree</td>
<td>summer</td>
<td>524</td>
<td>54</td>
<td>28</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Moree</td>
<td>winter</td>
<td>524</td>
<td>40</td>
<td>18</td>
<td>36</td>
</tr>
<tr>
<td>35°10’S</td>
<td>Walpeup</td>
<td>winter</td>
<td>336</td>
<td>60</td>
<td>9</td>
<td>11</td>
</tr>
</tbody>
</table>

a Fallow efficiency (%) = (gain in soil water / fallow rainfall) × 100.

b Fallow dependency (%) = (change in fallow soil water storage / transpiration) × 100.

The effects of tillage and stubble management practices on soil water accumulation, nutrition and crop production have been explored at a number of long-term research sites. In northern NSW, experiments were begun in 1981 at Breeza, Croppa Creek, Gurley, Warialda and Winton (Felton et al. 1995). In south-eastern Queensland, sites were established in 1968 at the Hermitage Research Station, near Warwick (Marley and Littler 1989; Thompson 1990, 1992a, 1992b; Thompson et al. 1995; Thomas et al. 2003); at Billa Billa, near Goondiwindi (Gibson et al. 1992; Radford et al. 1992; Thomas et al. 1995); and at Warra (Strong et al. 1996; Dalal et al. 1998). Thomas et al. (2007) summarised the key performance features of these and other long-term experiments (Table 2).

Table 2. Summary of key performance features of tillage experiments with winter and summer crops in southern and central Queensland, showing mean fallow efficiency (Freebairn et al. 1993), mean soil water storage at sowing and soil nitrate-N at sowing (Marley and Littler 1990; Radford et al. 1993; Thomas et al. 1995, 1997), and mean grain yield and protein content (Marley and Littler 1990; Thomas et al. 1995, 1997) with NT, stubble mulching or stubble incorporation. Reproduced from Thomas et al. (2007).

<table>
<thead>
<tr>
<th></th>
<th>Mean fallow efficiency (%)</th>
<th>Mean soil water storage at sowing</th>
<th>Mean soil nitrate N at sowing</th>
<th>Mean grain yield</th>
<th>Mean grain protein</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>b</td>
<td>b</td>
<td>b</td>
</tr>
<tr>
<td>Zero-tillage</td>
<td>21</td>
<td>113</td>
<td>76</td>
<td>111</td>
<td>94</td>
</tr>
<tr>
<td>Stubble mulching</td>
<td>19</td>
<td>108</td>
<td>80</td>
<td>109</td>
<td>96</td>
</tr>
<tr>
<td>Stubble incorporation</td>
<td>18</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Nº of experiment years</td>
<td>19</td>
<td>65</td>
<td>26</td>
<td>63</td>
<td>32</td>
</tr>
</tbody>
</table>

a Fallow efficiency (%) = (gain in soil water / fallow rainfall) × 100.

b Values are expressed as a percentage of stubble incorporation.
Under ZT, fallow efficiency, soil water storage and grain yield tended to be higher, but soil nitrate-N and grain protein content were lower than under stubble mulching (reduced tillage) and conventional tillage.

The true benefits of ZT, in terms of yield advantage, emerge in years when soil water supply is limited (Felton et al. 1995).

2.3. An integrated approach to cropping

A sustainable CA system, based on ZT, requires the integration of a number of components: herbicide management, crop choice and sequences, disease and pest strategies and nutrient management. The challenge for growers is to incorporate all of these interacting components into a system that maximises their benefits and minimises any negative impacts. Growers need to establish a cropping system plan that is flexible and based on sound agronomic rules.

The system must consider the needs of all crop sequences in terms of disease and weed management, not just the crop, because they are interdependent. For example, the loss of a grain legume or oilseed crop option from a cropping system due to disease will have profound effects on managing disease within the cereal phase.

The following cropping system plan is an example of how the system components can be integrated to maximise the storage and use of water and to enhance yields and sustainability (Table 3):

- It maximises soil plant-available water through the use of ZT and offsets the impact of high evaporative demand during flowering and grain-fill.
- In any one year of the sequence there is sufficient crop choice to respond to market signals.
- Crop sequencing optimises the management of soil and leaf diseases across all crops, not just cereals.
- Crop sequencing also allows the best use of herbicides to target grass and broadleaf weeds at specific phases in the cropping system.
- Crop sequencing spreads the use of different herbicide groups over the length of the cropping system, thus minimising the risk of herbicide resistance.
- Cropping frequency is controlled with only 1 summer crop and 1 winter break-crop every 5 years.
- Long fallows are limited to 2 or even 1 in 5 years, thus reducing the impact of excess water entering the system.

This system contains enough flexibility to respond to market signals and to allow for opportunity cropping. Individual fields can then be phased across the farm, in any one year, spreading both economic and environmental risks.
Table 3. Example of a 5-year ZT dryland cropping system with crop and fallow sequence, main and alternative crops, disease and weed actions, and herbicide group management (reproduced from Verrell 2004).

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>Summer</td>
<td>Winter</td>
<td>Summer</td>
<td>Winter</td>
</tr>
<tr>
<td>Main crop</td>
<td>Crop choice</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>Bread or durum wheat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fallow</td>
<td>Fallow</td>
<td>Pulse</td>
<td>Chickpea, faba bean, canola</td>
<td></td>
</tr>
<tr>
<td>Crop choice</td>
<td>Bread or durum wheat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fallow</td>
<td>Fallow</td>
<td>Chickpea, faba bean, canola</td>
<td>Wheat, barley</td>
<td></td>
</tr>
</tbody>
</table>

Disease key actions
Reduce winter cereal diseases
Reduce winter cereal diseases
Reduce broadleaf crop diseases

Weeds key actions
100% broadleaf weed control
100% summer weed control
100% grass weed control
100% broadleaf weed control
100% fallow weed control
100% summer weed control

Herbicide group management
B & I
M & I
C & A
M, B & I
B, I & K
M, I & C
C
M, I & B

2.4. Rates of adoption

In northern NSW, the percentage of crop area prepared by using CA practices changed from 8% by ZT and 48% by MT in 1996 to 24% and 47% in 2000 (Scott and Farquharson, 2004). A more recent survey determined the current status of NT and CA practices in major grain-growing regions of Australia: in northern NSW the percentage of crop area sown using ZT had increased to 74%, while that sown using MT declined to 16% (Table 4).

Table 4. Extrapolated area of cropping land sown using NT and NT sowing equipment with prior cultivation in 2008. Parentheses indicate the percentage of estimated total 2006–07 cropping area. Adapted from Llewellyn and D’Emden (2010).

<table>
<thead>
<tr>
<th>Region/state</th>
<th>Zero-till</th>
<th>Minimum-till</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern New South Wales</td>
<td>1 404 000 (74)</td>
<td>308 000 (16)</td>
</tr>
<tr>
<td>Southern Queensland</td>
<td>407 000 (59)</td>
<td>115 000 (17)</td>
</tr>
<tr>
<td>Victoria</td>
<td>1 327 000 (67)</td>
<td>167 000 (19)</td>
</tr>
<tr>
<td>South Australia</td>
<td>1 878 000 (70)</td>
<td>277 000 (10)</td>
</tr>
<tr>
<td>Western Australia</td>
<td>2 331 000 (86)</td>
<td>247 000 (5)</td>
</tr>
</tbody>
</table>

Pannell et al. (2006) identified 3 main criteria that aid the adoption of ZT:
- CA reduces erosion risk.
- Alternative tillage practices can be easily tested and compared by growers.
- ZT offers economic advantages, especially where herbicide prices decline relative to diesel costs.
In relation to this alt point, the falling price of glyphosate (Figure 1) had a significant positive effect on NT adoption rates in southern Australian (D’Emden et al. 2006). In 2007-08, the downward price trend rapidly reversed and glyphosate prices increased substantially. In the Llewellyn and D’Emden (2010) survey this price spike led to 21% of ZT users reporting increased use of tillage as a result (72% reported no change and 7% reported less tillage). This spike shows how sensitive growers are to price fluctuations.

The Llewellyn and D’Emden (2010) survey reported the following major findings:

- The proportion of growers using NT is starting to plateau near 90% in many districts.
- Rapid increases in adoption over the past 5 to 10 years have seen slow adopters catching up.
- Most growers who adopt NT use it on a large proportion of their crop area.
- Extensive use of NT is continuing. It is very uncommon for growers who adopt NT to drop it.
- Adoption levels in a few regions will remain lower, as a substantial proportion of growers do not expect to adopt in the medium term.
- The use of disc openers remains relatively low, except in NSW and southern Queensland.

\[\text{Figure 1. Roundup (glyphosate) prices in northern NSW (source: Mark Scott, NSW DPI, Orange, 2012).}\]
3  Agroecosystem impacts

3.1  Soil organic matter

The replacement of conventional tillage practices with CA has generally been accepted as increasing soil OC content. This change is attributed to the combined effect of increased OC inputs into the soil as a result of stubble retention and a reduced rate of breakdown of soil OM through reduced soil disturbance.

Increased soil OM contents following the adoption of CA have certainly been reported in some situations (Luo et al. 2010). However, in the grain-growing areas of subtropical Australia, results from trials conducted to compare NT with IA have produced inconsistent results, with 1 study reporting small increases in soil OM (in surface soil layers only) (Dalal et al. 2011), but others reporting that NT management has little impact (Standley et al. 1990; Dalal et al. 1995; Armstrong et al. 2003). Dalal et al. (2012) compared the current soil carbon status of 3 long-term sites (Table 5) with earlier sampling times. At all 3 sites, there was no evidence that NT management had increased soil OM contents. While NT treatments at Hermitage and Goodger often had higher soil OM relative to IA treatments, longitudinal sampling showed that soil OM decreased in all treatments regardless of the management system used.

Dalal et al. (2012) considered that the fallow period, which is characterised by high rates of decomposition, combined with low levels of crop stubble input led to an overall soil OM decrease regardless of the tillage or stubble management techniques used. Similar conclusions have been reached in studies in other parts of Australia (southern NSW, Heenan et al. 1995; northern NSW, Young et al. 2009), and from meta-analyses conducted worldwide (West and Post 2002; Ogle et al. 2005).

Table 5. Selected characteristics of Australian subtropical trial sites.

<table>
<thead>
<tr>
<th>Site</th>
<th>Rainfall (mm) a</th>
<th>Soil type b</th>
<th>Treatments</th>
<th>Sampling years</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biloela</td>
<td>627</td>
<td>Vertosol</td>
<td>Cultivation (CT vs. NT)</td>
<td>1984, 1989, 2010</td>
<td>Radford et al. 1995</td>
</tr>
<tr>
<td>Hermitage</td>
<td>701</td>
<td>Vertosol</td>
<td>2 x 2 x 2 factorial:</td>
<td>1981, 2008</td>
<td>Dalal et al. 2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cultivation (CT vs. NT)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Residue (burnt vs. retained)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>N fertilizer (0 vs. 90 kg/ha)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goodger</td>
<td>753</td>
<td>Oxisol</td>
<td>Cultivation (CT vs. NT)</td>
<td>1994, 2010</td>
<td>Bell et al. 1997</td>
</tr>
</tbody>
</table>

a 30-year average rainfall.
b US Soil Taxonomy soil classification.
CT = conventional tillage, NT = no-tillage.
The Hermitage site, which was established in 1968 with treatments maintained continuously since, provides some clear insights. When a single point in time is considered (e.g. the 2008 sampling), clear benefits of CA are apparent in the 0-10 cm soil layer (Fig. 2), and this could readily lead to the view that CA increases soil OM. The NT treatment had higher soil OC than the Tillage treatment (20.6 vs. 20.1 Mg/ha), stubble retention had higher soil OC than stubble burning (20.9 vs. 19.8 Mg/ha), and nitrogen (N) application resulted in higher soil OC than no application (20.9 vs. 19.8 Mg/ha). There were also significant cultivation x stubble and stubble x fertiliser interactions, which meant that the effect of NT was significant only where stubble was also retained, and stubble retention led to higher soil OC only where N fertiliser was applied.

Soil OC was highest where all 3 management practices (NT, stubble retention, fertiliser application) were used. It is important to note that when the soil OC stocks in the top 30 cm of soil were considered, there were no significant differences. Indeed, the effect of NT on soil OC at 10–30 cm was slightly negative, a result widely reported for NT systems (Baker et al. 2007).

The longitudinal assessment of this trial (2008 vs. 1981) provided a result in stark contrast to the optimistic view formed from a single assessment. In all treatments, soil OC decreased over this 27-year period, with soil OC loss across the trial averaging 7.8 Mg/ha in top 30 cm, and 2.9 Mg/ha in the top 10 cm. Nevertheless, CA practices resulted in lower rates of soil OC loss (Fig. 3).

**Figure 2.** Differences in soil organic carbon stocks (Mg/ha) at 0–10 cm due to tillage, stubble management and N treatments in the Hermitage trial, 2008. NT = no-till; CT = conventional tillage; SB = stubble burnt; SR = stubble retained; N0 = no N applied; N90 = 90 kg-N/ha applied. The least significant difference for the cultivation x stubble and stubble x fertiliser interactions is 0.6 Mg/ha. Reproduced from Dalal et al. (2012).
Figure 3. Change in soil organic carbon (Mg/ha) at 0–10 cm between 1981 and 2008 due to tillage, stubble and N treatments in the Hermitage trial. Key is as for Figure 2. The least significant difference is 0.9 Mg/ha. Reproduced from Dalal et al. (2012).

3.2. Soil water relationships

Water use efficiency (WUE) is improved under CA practices, and is generally linked to higher OM contents and increased soil fauna biodiversity. Soil structure, plant-available water (PAW) and nutrients, and soil hydraulic properties are closely related to soil OM contents. However, the relative importance of the contribution of OM to soil quality needs to be assessed in relation to the contribution to the entire soil profile. Increases of 2-4 mm of PAW with a 1% increase in soil OC in 10 cm of soil seem common for a wide range of soils worldwide (Manrique et al. 1991; Kay et al. 1997; DaSilva and Kay 1997; Kirchhof et al. 2000). But as most OM is located in the top 10 cm of the soil, even an increase as large as 1% OC (~1.75% OM) would increase the amount of PAW by no more than 4 mm over the entire profile. In some soils such as Vertosols and Ultisols there may be no detectable effect of OM on PAW (Manrique et al. 1991). Unless soils are very sandy, the increase in potential PAW over the rooting depth may be small, but the increase in actual PAW can be large, owing to the increased ability of the soil to take up water due to high infiltration rates.

A survey in northern NSW showed that saturated hydraulic conductivity on virgin black Vertosols was similar to that on virgin pasture sites (Figure 4). Converting natural grassland to pasture does not require excessive land clearing. Owing to the resilient nature of these soils, livestock had little impact on soil permeability. Conventional tillage substantially reduced soil permeability. Changing to CA increased permeability and had a rapid impact on the soils' ability to take up water, and after more than 3 years the permeability increased over and above that of the virgin vegetation. These are soils that respond rapidly to MT, and are also the soils where CA can result in increased yields, despite there being no change in OC content.
Figure 4. The effect of land use and tillage practices on saturated hydraulic conductivity of swelling clay soil (‘conventional’ = always tilled; ‘changed’ = CA adopted 3 years ago; ‘conservation’ = CA used since fields were first cropped, 3–10 years ago). After Kirchhof and Daniells (2009).

Figure 5. The effect of land use and tillage practices on total organic carbon of swelling clay soil (‘conventional’ = always tilled; ‘changed’ = CA adopted 3 years ago; ‘conservation’ = CA used since fields were first cropped, 3–10 years ago). After Kirchhof and Daniells (2009).
The improvement in soil structure was most likely due to a reduction of soil compaction associated with reduced wheel traffic. In contrast to the strong effect of tillage history on the permeability of black Vertosols, there was little effect of tillage practice on grey and brown Vertosols (Fig. 5).

These are less active soils and tend to have a lower clay content. However, the change from virgin vegetation to pasture tended to reduce soil permeability strongly, particularly in the top 10 cm. This was probably a reflection of compaction by livestock. Similar to the black Vertosols, there was no change in OC (Fig. 5), but in contrast to the black Vertosols, saturated hydraulic conductivity under tillage was not different from that under ZT.

This survey showed clearly that different soils, even within the same soil order, respond differently to the adoption of NT practices. At the time this survey was conducted, ZT was used only on the Vertosols in that region; the red hardsetting loamy soils were all still under tillage. This is most likely due to the slow positive response of the more ‘difficult’ soils to reduced tillage. The same is most likely to apply to other soils that set hard, particularly if they are degraded and have low OM.

### 3.3. Nutrient stratification

Nutrient stratification has long been recognised to result from NT practices. Stratification is more profound for nutrients which are relatively immobile in the soil (e.g. phosphorus), with surface application of fertilizer and cycling of nutrients though the crop both contributing to near-surface accumulation (Lupwayi et al. 2006). Stratification of potassium (K) is particularly rapid because of the relatively large amount of K accumulated in the crop canopy. While root morphological plasticity (Drew 1975) ensures that roots will proliferate in the zone of nutrient accumulation, nutrients accumulated near the surface may nevertheless not be available, because the surface soil is more prone to drying out. Studies in North America have indicated that despite K stratification, tillage practice did not affect K uptake (Lupwayi et al. 2006).

However, these studies were conducted on soils relatively well supplied with K. In the Australian subtropics, where soil nutrient status is typically inherently low and K fertilization is less than crop removal, profound K stratification occurs under NT management (Fig. 6). While the potential for yield loss has not been demonstrated, transitory K deficiency has been observed when the surface soil dries during the rapid K accumulation phase of crop growth; this K deficiency is relieved as the crop roots gain access to the surface soil following rain or irrigation.

One-time infrequent (e.g. 5-year cycle) tillage has been suggested as a strategy to reduce nutrient stratification, and to address other problems such as the build-up of herbicide-resistant weeds. The approach can resolve the problem without apparent detrimental effects on soil quality, but nutrient stratification does re-establish over time (Wortmann et al. 2010).
Figure 6. The distribution of K with depth in a virgin grassland site and in adjacent fields under intensive agriculture with conventional tillage (CT) and no-till (NT) practices. Left: K concentrations in the soil at each depth; right: proportion of the total soil K stock to 50 cm present in each depth increment.

3.4. Herbicide resistance

CA relies on herbicide weed control. Unfortunately, for conservation farmers in most grain-growing regions, herbicide-resistant weeds now pose a considerable problem (e.g. Llewellyn and Powles 2001), with an increasing prevalence of resistance to glyphosate and multiple modes of action (Preston 2012) (Fig. 7).

Figure 7. The increase in confirmed cases of glyphosate-resistant annual ryegrass (left) and summer weeds (right). Reproduced from Preston (2012).

The first glyphosate-resistant weed identified was rigid ryegrass (Lolium rigidum Gaudin) in 1996 in Australia, followed by other biotypes in the USA (1998), South Africa (2001) and France (2005) (Heap 2008).

Typically, as tillage intensity decreases (mouldboard > chisel > NT), total weed density decreases, but weed species diversity increases. Increased species diversity increases the possibility of enhancing the populations of weeds that have greater tolerance to the herbicides used in that system.
In addition to tillage practices, the cropping sequence also plays a role in determining weed pressure and the likelihood that herbicide-resistant weeds will emerge. Crop rotations help to alleviate selection pressure by diversifying the patterns of disturbance, by shading and by preventing the proliferation of weed species adapted to the agronomy of a particular crop (Buhler et al. 1997). Cardina et al. (2002) found that under NT, a maize–maize rotation had a 45% greater seedbank of *Oxalis stricta* L. and *Stellaria media* (L.) Vill. than a maize–oats (*Avena sativa* L.)–lucerne (*Medicago sativa* L.) rotation. While crop rotation clearly confers advantages, in many situations these advantages are outweighed by other constraints, and a single crop species is grown in most years.

The adoption of CA gained impetus with the introduction in 1996 of transgenic, glyphosate-resistant crops. This technology permits in-season, over-the-top use of glyphosate for weed control. In countries where the technology has been adopted, glyphosate use has increased dramatically; in the USA, use on maize, cotton and soybean increased 8-fold in the 10 years following introduction (USDA-NAAS 2008).

One of the undesirable consequences of this new technology has been the emergence and rapid spread of new glyphosate-resistant weeds.

Herbicide resistance is probably the greatest single threat to our current CA practice. This threat, and specifically that posed by resistant *Amaranthus palmeri* S.Wats., is well summarised by Price et al. (2011): ‘Hundreds of thousands of conservation tillage hectares are at risk of being converted to higher-intensity tillage systems due to the inability to control these glyphosate-resistant *Amaranthus* species in conservation tillage systems using traditional technologies. The decline of conservation tillage is inevitable without the development and rapid adoption of integrated, effective weed control strategies.’

### 4 The way forward

CA provides a range of benefits. Nevertheless, we believe that it is necessary to recognise that for various biophysical and social reasons, it is not advantageous for all farmers to adopt all aspects.

To some extent, the existing promotion of CA could be characterised as ‘You must adopt fully, and you will receive all of the benefits.’ Consequently, where CA has not worked well, there is the suspicion that the farmers have not ‘done it properly’.

We believe that it is time to move to a more mature stance, recognising that CA practice needs to be adapted to fit into the broad range of agricultural environments (climate, soil, crop, society). Furthermore, it is important to recognise that in its various forms in these different environments, CA will deliver different benefits. Our way forward must be to better understand how CA needs to be modified to fit different environments, and what benefits farmers can then expect.
References


Bibliography


When, how and why does no-till farming work?

J.C.M Sá*, F. Tivet, R. Lal and L. Séguy

1 Universidade Estadual de Ponta Grossa, Departamento de Ciência do Solo e Engenharia Agrícola, Av. Carlos Cavalcanti 4748, Uvaranas 84030-900, Ponta Grossa-PR, Brasil
2 CIRAD, UPR SIA, F-34398 Montpellier, France
3 Carbon Management and Sequestration Center, School of Environment and Natural Resources, OARDC/FAES, Ohio State University, 2021 Coffey Road, Columbus, OH 43210, USA

*Corresponding author: jcmsa@uepg.br; Tel/Fax: +55 42 3220 30 90/72

In an undisturbed soil under natural vegetation, biogeochemical cycles are driven by interlinked natural factors such as climate, soil type, parent material, topography, vegetation and organisms. The overall impact of the conversion to agriculture through the clearing and burning of vegetation and tilling of the soil is the disruption of the entire soil structure (Guo and Gifford 2002; Sá et al. 2012; Tivet et al. 2013). Continuous tillage causes soil degradation seen as erosion, loss of organic matter, loss of soil fertility and physical constraints on the growing of crops. Although there is much scientific information on no-till (NT) culture, there is wide discussion about when, how and why NT works. Answering these questions relies on the concept that NT tries to mimic the undisturbed soil under natural vegetation as the baseline for soil functionality.

Therefore, what are we looking for from natural soils in growing crops? How far are our cropped soils from natural? What scientific evidence shows when, how and why NT works?

To answer these questions, we hypothesised that carbon inputs must exceed microbial losses, and so keeping the soil covered will restore the soil organic carbon (SOC) and soil structure. Our objectives were to quantify the impact of plough-based tillage on SOC losses; to quantify the influence of C enhancement on soil attributes in relation to cropping systems diversification and intensity; to identify the mechanisms that control C accumulation; and to evaluate the redistribution of SOC stock in the soil profile in relation to soil resilience.

We conducted field experiments at 3 research sites: at the Instituto Agronômico do Paraná (IAPAR) and at the ABC Foundation, both near the town of Ponta Grossa, Paraná State, in southern Brazil; and at the Fundação Rio Verde (FRV), near the city of Lucas do Rio Verde, Mato Grosso State, in central-western Brazil. The IAPAR and ABC experiments compared conventional tillage (CT), minimum tillage and NT. The FRV experiment compared the standard tillage management of the region (CT) with NT using different inputs of biomass (NT1-6).
The continuous use of tillage depleted SOC stocks in the top 20 cm of the soil by 0.60 (ABC), 0.58 (IAPAR) and 0.67 (FRV) Mg ha\(^{-1}\) y\(^{-1}\). NT increased SOC sequestration in the top 20 cm by 1.92 (ABC) and 0.59 (IAPAR) Mg C ha\(^{-1}\) y\(^{-1}\) (subtropical region), and by 0.48–1.30 Mg C ha\(^{-1}\) y\(^{-1}\) (FRV; tropical region). The rates of SOC sequestration in the top 40 cm increased from 0.73 (NT3) to 1.98 (NT5) Mg C ha\(^{-1}\) y\(^{-1}\), which represented an increase of ~50% in the 20–40-cm layer. Laser-induced fluorescence spectroscopy indicated that the degree of aromaticity was larger under CT than under NT and natural vegetation in the top 20 cm, indicating a general depletion of labile functional C groups under CT. The resilience index (RI) was 0.69 under NT at the ABC site, and ranged from 0.29 (NT3) to 0.79 (NT5) at the FRV site as dry matter inputs increased (RI = 0.18 x C-input – 0.76; \(r^2 = 0.88\), P < 0.001).

These results indicate the potential for biomass-C input under NT to restore SOC depleted by intensive tillage. The highest RI is associated with the highest rate of SOC sequestration (NT5), confirming the strong relationship between these parameters. A high SOC resilience under tropical NT systems indicates a considerable potential to reverse the process of soil degradation and SOC decline by conversion to intensive NT systems (with high and diversified annual C inputs). The biomass-C needed to maintain a positive C balance is estimated at ~5.5 (FRV) and ~4.0 (ABC) Mg C ha\(^{-1}\) y\(^{-1}\) (≈ 12.5 and 8.0 Mg ha\(^{-1}\) of dry matter). Every 1 t increase in SOC stock to 1 m depth increased soybean yield by 28 kg ha\(^{-1}\), and every 0.1 unit increase in RI increased it by 600 kg ha\(^{-1}\). The results support the hypothesis that SOC can be restored through the intensification of NT cropping systems, which maintain a continuous input of biomass-C into the soil.

**Keywords**

Soil organic carbon, Brazil

**References**


Soils can be a sink or a source of atmospheric CO2 depending on temperature, precipitation, mineralogy, net primary production, land use and management. Land use change -conversion of native vegetation (NV) to agricultural land- exacerbates CO2 emissions through deforestation, biomass burning and depletion of soil organic carbon (SOC) by conventional plough-based tillage (CT).

The data on SOC sequestration rates for tropical (−0.03 to 1.9 Mg ha−1 y−1) and subtropical (−0.07 to 1.4 Mg ha−1 y−1) regions of Brazil vary widely because of differences in the amount of biomass-C inputs and the agronomic potential of agroecosystems (Batlle-Bayer et al. 2010). The large variability may be attributable to the high diversity of cropping systems, amount and frequency of biomass-C inputs, and soil properties.

Cropping systems with a high biomass input support a continuous flow of mass and energy, which release organic compounds, accentuate soil biodiversity and enhance soil organic matter (SOM) (Séguy et al. 2006). These processes are driven by the multi-functionality of each species in the cropping system and the species’ interactions with soil attributes, stimulating a systemic interdependence of soil structure and SOM pools (Uphoff et al. 2006).

The continuous input of large amounts of biomass to the soil surface creates a positive C budget, and accentuates C and N transformations and flow (Sá et al. 2001). We tested the hypothesis that the intensification of cropping and the attendant increases in C-input and biodiversity under NT restore the SOC pool and increase the resilience of degraded agroecosystems.

Our objectives were to quantify the impact of plough-based tillage (CT) on SOC stock, to evaluate the recovery of SOC under NT with diverse biomass-C inputs, and to assess the changes in humification index among land uses by laser-induced fluorescence spectroscopy (LIFS).
Field experiments were conducted at 2 research sites: the Instituto Agronômico do Paraná (IAPAR), near the town of Ponta Grossa, Paraná State, in southern Brazil (25°09’S, 50°09’W, 865 m a.s.l.); and at the Fundação Rio Verde (FRV), near the city of Lucas do Rio Verde, Mato Grosso State, in central-western Brazil (13°00’S, 55°58’W, 380 m a.s.l.).

At IAPAR, the experiment began in 1981 with CT, no-till (NT) and minimum-tillage (MT). All treatments used a 3-year cropping sequence with 2 crops per year; during the last 10 years, soybean (Glycine max) in 6 summers and maize (Zea mays) in 4 summers alternated with oats (Avena strigosa), wheat (Triticum aestivum) and vetch (Vicia sativa) in winter.

At FRV, the experiment began in 2001 with CT (soybean alternating with cotton; Gossypium hirsutum) and 6 different biomass-C inputs under NT. Treatments NT1–6 alternated soybean in summer with various second crops: NT1, soybean followed by maize + Brachiaria ruziizensis; NT2, soybean followed by finger millet (Eleusine coracana) or finger millet + pigeon pea (Cajanus cajan); NT3, soybean followed by finger millet + pigeon pea or finger millet + Crotalaria spectabilis; NT4, soybean followed by finger millet + C. spectabilis or sunflower (Helianthus annuus) + B. ruziizensis; NT5, soybean followed by sorghum (Sorghum bicolor) + B. ruziizensis; and NT6, soybean followed by millet (Pennisetum glaucum) or maize + B. ruziizensis.

At both sites, an adjacent area under NV was selected as a baseline against which to assess SOC changes. Soil samples were collected in 2009 from 7 depths: 0–5, 5–10, 10–20, 20–40, 40–60, 60–80 and 80–100 cm. Soil bulk density was measured in 5-cm cores. Bulk samples were oven-dried at 40 °C, gently ground, sieved through a 2-mm sieve and mixed. Subsamples of <2 mm bulk soil were finely ground (<150 µm) for measuring SOC and total N concentrations by dry combustion in an elemental CN analyser (TruSpec CN; LECO, St Joseph, MI, USA). The SOC stocks were estimated to 1-m depth and computed on an equivalent soil mass–depth basis. The humification index (HLIF) was determined by LIFS and by the procedure described by Milori et al. (2006) (HLIF = fluorescence curve area / TOC concentration).

At IAPAR, the average SOC stock at 0–20 cm decreased from 92.0 Mg ha–1 under NV to 67.4 Mg ha–1 under CT (P < 0.001), a decline of ~27% over the 42 years since the conversion of NV and the use of tillage for 29 years (Table 1). SOC was 17.0 Mg ha–1 higher and N was 2.02 Mg ha–1 higher under NT than under CT at 0-20 cm. These data represent an annual accumulation rate of 0.59 Mg C ha–1 and 69.7 kg N ha–1 over 29 years under NT.

At FRV, the soil under NT, with a predominance of cereals as the second crop (maize + B. ruziizensis, sorghum + B. ruziizensis, millet) during the dry season, and with a higher biomass input (NT1, NT5 and NT6), contained, on average, higher SOC and N concentrations at 0–5 cm than the soil under CT (23.6–25.2 vs. 18.3 g C kg–1; 1.2–1.4 vs. 0.92 g N kg–1).
The difference in SOC stock between CT and NV was 14.2 Mg C ha\(^{-1}\) at 0–20 cm and 5.9 Mg C ha\(^{-1}\) at 20–40 cm (Table 1). The total difference at 0–40 cm (20.1 Mg C ha\(^{-1}\)) represented a 27% decrease over 23 years of CT, with an average rate of loss of 0.88 Mg C ha\(^{-1}\) y\(^{-1}\). In contrast, the SOC stock at 0–20 and 20–40 cm under NT1, NT5 and NT6 was similar to that under NV. Relative to CT, SOC accumulated at 0.48–1.30 Mg C ha\(^{-1}\) y\(^{-1}\) under NT. The SOC resilience index \(((\text{SOC}_{\text{NT}} - \text{SOC}_{\text{CT}})) / (\text{SOC}_{\text{NV}} - \text{SOC}_{\text{CT}}))\) ranged from 0.29 to 0.79, and increased with increasing C input among NT systems.

HLIF was lower in NT soils at both locations because of aggregation, which protects most labile moieties. The depletion of C concentration in CT was related to an overall increase in humification, especially in the surface layer.

LIFS indicated that the degree of aromaticity was larger under CT than NT and NV in the top layer of soil, indicating that aggregation was inadequate to protect the most labile SOM fraction under CT. Under NT at FRV, SOC accumulation increased with increasing input of biomass-C. A high SOC resilience under the tropical NT systems indicates a considerable potential to reverse the process of soil degradation and SOC decline by conversion to intensive NT systems (with high and diversified annual C inputs). The results support the hypothesis that SOC can be restored through the intensification of NT cropping systems, which maintain a continuous input of biomass-C into the soil.

**Keywords**

C-input, soil C sequestration, land use conversion, soil resilience

**References**


Table 1. Soil organic C (SOC) and total nitrogen stocks at IAPAR and FRV under different tillage treatments and under neighbouring native vegetation (NV) by depth.

<table>
<thead>
<tr>
<th>Site</th>
<th>Land use</th>
<th>Soil depth (cm)</th>
<th>SOC stock, t ha(^{-1})</th>
<th>Total N stock, t ha(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0-20</td>
<td>20-40</td>
<td>40-60</td>
</tr>
<tr>
<td>IAPAR</td>
<td>NV</td>
<td>92.0</td>
<td>53.7</td>
<td>44.0</td>
</tr>
<tr>
<td></td>
<td>CT</td>
<td>67.4</td>
<td>52.9</td>
<td>48.1</td>
</tr>
<tr>
<td></td>
<td>MT</td>
<td>70.2</td>
<td>49.4</td>
<td>43.3</td>
</tr>
<tr>
<td></td>
<td>NT</td>
<td>84.4</td>
<td>53.2</td>
<td>47.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td>P values</td>
<td>&lt;0.0001</td>
<td>0.625</td>
<td>0.403</td>
</tr>
<tr>
<td>FRV</td>
<td>NV</td>
<td>48.0</td>
<td>27.7</td>
<td>20.9</td>
</tr>
<tr>
<td></td>
<td>CT</td>
<td>33.8</td>
<td>21.8</td>
<td>17.3</td>
</tr>
<tr>
<td></td>
<td>NT1</td>
<td>44.2</td>
<td>25.1</td>
<td>18.1</td>
</tr>
<tr>
<td></td>
<td>NT2</td>
<td>39.5</td>
<td>25.8</td>
<td>18.8</td>
</tr>
<tr>
<td></td>
<td>NT3</td>
<td>37.7</td>
<td>23.7</td>
<td>18.1</td>
</tr>
<tr>
<td></td>
<td>NT4</td>
<td>37.7</td>
<td>27.5</td>
<td>19.5</td>
</tr>
<tr>
<td></td>
<td>NT5</td>
<td>43.3</td>
<td>28.1</td>
<td>19.0</td>
</tr>
<tr>
<td></td>
<td>NT6</td>
<td>40.7</td>
<td>26.5</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>P values</td>
<td>0.023</td>
<td>0.055</td>
<td>0.207</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IAPAR</td>
<td>NV</td>
<td>6.03</td>
<td>3.22</td>
<td>2.21</td>
</tr>
<tr>
<td></td>
<td>CT</td>
<td>3.49</td>
<td>2.38</td>
<td>2.14</td>
</tr>
<tr>
<td></td>
<td>MT</td>
<td>4.32</td>
<td>2.68</td>
<td>2.41</td>
</tr>
<tr>
<td></td>
<td>NT</td>
<td>5.51</td>
<td>2.81</td>
<td>2.18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td>P values</td>
<td>0.001</td>
<td>0.305</td>
<td>0.929</td>
</tr>
<tr>
<td>FRV</td>
<td>NV</td>
<td>2.20</td>
<td>1.33</td>
<td>1.07</td>
</tr>
<tr>
<td></td>
<td>CT</td>
<td>1.72</td>
<td>1.00</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>NT1</td>
<td>2.13</td>
<td>1.07</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>NT2</td>
<td>1.85</td>
<td>0.94</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td>NT3</td>
<td>1.78</td>
<td>0.97</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>NT4</td>
<td>1.62</td>
<td>1.24</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>NT5</td>
<td>1.93</td>
<td>1.19</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>NT6</td>
<td>2.07</td>
<td>1.21</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>P values</td>
<td>0.236</td>
<td>0.612</td>
<td>0.995</td>
</tr>
</tbody>
</table>
Enhancing soil fertility and quality through conservation agriculture in the acid savannah grasslands of northern Laos

Pascal Lienhard*1,2, Moundavi Manivong3, Bounma Leudphanane4, Somchay Chantavong2, Phackphoom Tantachasatid5 and Johnny Boyer1,5

1 CIRAD, UR SIA, F-34398 Montpellier Cédex 5, France
2 NAFRI, NCAC, PO Box 7170, Vientiane, Lao PDR
3 Nabong Faculty of Agriculture, Vientiane, Lao PDR
4 PROSA / MAF, PO Box 10118, Vientiane, Lao PDR
5 Kasetsart University, Soil Biology Laboratory, Sakon Nakhon, Thailand

*Corresponding author: pascal.lienhard@cirad.fr

The Plain of Jars is a vast, acidic, infertile savannah grassland located in the western part of Xieng Khouang Province, north-eastern Lao PDR. The farming systems in this region are based mainly on lowland rice cultivation and extensive livestock production. With limited opportunities for agricultural expansion in the lowlands, the development of agricultural production in the uplands is a key challenge for subsistence farmers. Conservation agriculture (CA) has been shown to be a valuable option for the increase and diversification of agricultural production and farmers’ income in this agroecology (Lestrelin et al. 2012). However, little is known regarding the impact of CA on soil fertility and quality, notably in tropical areas, on strongly acidic, weathered soils (Six et al. 2002, Lienhard et al. 2012). This paper presents an early evaluation of the impact of CA on soil fertility and quality as estimated by soil chemical properties and soil microbial abundance.

Field monitoring was conducted in 18 plots within 12 villages. We evaluated the effects of 2 CA farming systems: a cattle-based system involving the fattening of young bulls on direct-sown improved pasture of Brachiaria ruziziensis (CA-ImpP-ruzi; 12 plots, 3 years of age); and a rice-based system involving the cultivation of relay crops (Stylosanthes guianensis, Cajanus cajan, Eleusine coracana) before or after rice (CA-crops; 6 plots, 4 years of age). All CA treatments were compared with the surrounding natural pasture (nat pasture; 14 plots).

Soil samples were collected in September 2010 at 3 depths (0–10, 10–20, 20–30 cm). Each sample was a bulk of 5 subsamples taken across the diagonal of the plots. The samples were air-dried and passed through a 2-mm-mesh sieve before being sent for chemical and biological analysis.

Soil chemical properties were analysed in Khon Khaen, Thailand; 96 samples were analysed for soil pH (1:1 in water), soil organic carbon (SOC, Walkley Black), available P (Bray II), CEC (Metson) and exchangeable bases (Ca, Mg, K, Na) (Metson).
The soil microbial carbon content was analysed in Sakon Nakhon, Thailand, by a “fumigation-extraction” method; 64 samples were analysed (0–10 cm and bulk of 0–30 cm) with 2 titration replicates per sample.

The soil chemical properties (pH, SOC, P and sum of exchangeable bases) and microbial carbon content were improved under both CA systems at all soil depths, relative to the natural surrounding pastureland. These results agree with a previous study conducted under controlled conditions and limited to the effect of CA on topsoil (0–10 cm) properties (Lienhard et al. 2012). CA is thus a valuable option to develop sustainable rainfed agriculture on tropical acidic soils.

Table 1. Soil chemical and microbial properties by depth and land use management.

<table>
<thead>
<tr>
<th>Depth</th>
<th>pH (H₂O)</th>
<th>SOC WB (mg kg⁻¹)</th>
<th>P Bray II (mg kg⁻¹)</th>
<th>CEC (cmol kg⁻¹)</th>
<th>∑ bases (cmol kg⁻¹)</th>
<th>Microbial C (mg kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10 cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nat pasture</td>
<td>4.8 ± 0.1 [a]</td>
<td>25.9 ± 6.7 [b]</td>
<td>1.2 ± 0.3 [b]</td>
<td>12.8 ± 3.0 [b]</td>
<td>2.0 ± 0.2 [b]</td>
<td>611 ± 138 [a]</td>
</tr>
<tr>
<td>CA-crops</td>
<td>4.9 ± 0.2 [a]</td>
<td>35.1 ± 7.5 [b]</td>
<td>8.5 ± 3.5 [a]</td>
<td>19.2 ± 5.5 [a]</td>
<td>4.1 ± 0.6 [a]</td>
<td>671 ± 136 [a]</td>
</tr>
<tr>
<td>CA-ImpP-ruzi</td>
<td>4.9 ± 0.2 [a]</td>
<td>32.0 ± 10.5 [a]</td>
<td>4.2 ± 2.5 [a]</td>
<td>18.0 ± 4.0 [a]</td>
<td>3.1 ± 1.0 [a]</td>
<td>882 ± 264 [a]</td>
</tr>
<tr>
<td>0-30 cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nat pasture</td>
<td>4.8 ± 0.1 [a]</td>
<td>19.5 ± 4.1 [b]</td>
<td>1.1 ± 0.4 [b]</td>
<td>14.3 ± 2.4 [b]</td>
<td>1.4 ± 0.2 [b]</td>
<td>434 ± 158 [a]</td>
</tr>
<tr>
<td>CA-crops</td>
<td>4.8 ± 0.1 [a]</td>
<td>27.3 ± 3.7 [a]</td>
<td>4.1 ± 1.5 [a]</td>
<td>19.8 ± 4.9 [a]</td>
<td>2.5 ± 0.4 [a]</td>
<td>671 ± 244 [a]</td>
</tr>
<tr>
<td>CA-ImpP-ruzi</td>
<td>4.9 ± 0.1 [b]</td>
<td>25.3 ± 7.5 [a]</td>
<td>2.4 ± 0.9 [a]</td>
<td>19.4 ± 4.7 [a]</td>
<td>2.0 ± 0.4 [a]</td>
<td>662 ± 129 [a]</td>
</tr>
</tbody>
</table>

Letters in brackets indicate significant differences (ANOVA and Fisher’s LSD test with P < 0.05).

Keywords

No-till, soil chemical properties, microbial abundance, tropical acid soil, sustainable management

References


Differential effects of biochar on soil organic carbon dynamics in two agricultural soils

Sudip Mitra*, Pooja¹, S. Manzoor¹, T. Bera² and A.K. Patra²

¹ School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110067, India
² Division of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, Pusa, New Delhi 110012, India

*Corresponding author: sudipmitra@yahoo.com

The atmospheric concentration of CO₂ is now 389 ppm (Conway and Tans 2012) and is increasing at a rate of 1.9 ppm y⁻¹. One method of carbon capture is sequestration in soils - in particular, as biochar (Czimczik and Masiello 2007). In contrast to the open burning of agricultural wastes, which emits large amounts of greenhouse gases (GHGs) into the atmosphere, the preparation of biochar from the wastes and its incorporation into soil can not only mitigate GHGs to an extent, but can significantly improve soil fertility and crop yields (Lehmann et al. 2006; Major et al. 2010).

Biochar is produced by the pyrolysis of biomass at temperatures between 350 and 700 °C. The temperature affects the biochemical properties of the biochar, which in turn affect agronomic performance. Biochar is considered to have a long mean residence time in soil (Cross and Sohi 2011).

Different source materials confer different physicochemical properties on the biochar (Table 1). Soil properties, biochar properties, incorporation rate and environmental factors can all influence the C and N dynamics of the soil, GHG emissions and crop yields (Czimczik and Masiello 2007; Cross and Sohi 2011).

Table 1. Total N and C contents rice and wheat biochar.

<table>
<thead>
<tr>
<th></th>
<th>Total N (%)</th>
<th>Total C (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice biochar</td>
<td>1.590</td>
<td>46.36</td>
</tr>
<tr>
<td>Wheat biochar</td>
<td>1.885</td>
<td>56.39</td>
</tr>
</tbody>
</table>

We studied the loss of CO₂ from 2 different soils (Table 2) amended with different rates of wheat and rice biochar (which have entirely different morphologies), with and without fertiliser, in an incubation study over 90 days.

Red and alluvial soils were amended with biochar at rates equivalent to 0, 5, 10 and 15 Mg ha⁻¹, with or without fertiliser. The soils were maintained at field capacity and incubated at 28 °C in 500-mL conical flasks. To trap CO₂, 20 mL of 0.5 N NaOH in a 30-mL glass vial was suspended in the flasks.
Table 2. Basic properties of red and alluvial soils.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Red soil</th>
<th>Alluvial soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.4</td>
<td>6.2</td>
</tr>
<tr>
<td>Eh</td>
<td>300 mV</td>
<td>211 mV</td>
</tr>
<tr>
<td>Total C</td>
<td>0.98%</td>
<td>3.056%</td>
</tr>
<tr>
<td>Organic C</td>
<td>0.44%</td>
<td>0.55%</td>
</tr>
<tr>
<td>P</td>
<td>48.6 ppm</td>
<td>43.8 ppm</td>
</tr>
<tr>
<td>K</td>
<td>0.91 ppm</td>
<td>1.43 ppm</td>
</tr>
</tbody>
</table>

Total CO₂ released was determined by titration with H₂SO₄ at 1, 2, 4, 7, 11, 17, 25, 39, 60 and 88 days after incubation (DAI), in the presence of BaCl₂ and pinch of indicator.

In the absence of fertiliser, the mean CO₂ emission from wheat biochar was higher in alluvial soil (0.172 mg g⁻¹ d⁻¹ at 10 Mg biochar ha⁻¹) than in red soil (0.154 mg g⁻¹ d⁻¹), but that from rice biochar was lower in alluvial soil (0.1693 mg g⁻¹ d⁻¹) than in red soil (0.1718 mg g⁻¹ d⁻¹).

In the presence of fertiliser in red soil, the mean CO₂ emission from rice biochar was higher (0.1776 mg g⁻¹ d⁻¹) than from wheat biochar (0.1445 mg g⁻¹ d⁻¹). In the presence of fertiliser in alluvial soil, in contrast, the mean CO₂ emission from wheat biochar was higher (0.163 mg g⁻¹ d⁻¹) than from rice biochar (0.153 mg g⁻¹ d⁻¹). CO₂ emissions from rice biochar in alluvial soil were lowest at 15 Mg ha⁻¹, with or without N (Fig. 1); the reduction was greatest without fertiliser. In contrast, emissions from wheat biochar were lowest at 5 Mg ha⁻¹, with or without fertiliser.

Rice biochar was more prone to degradation than wheat biochar in red soil, but more resistant in alluvial soil. In addition, in alluvial soil, CO₂ loss was minimised at the highest rate of rice biochar but at the lowest rate of wheat biochar. These results offer clues to management practices that can curb CO₂ emission from agricultural soils.

Figure 1. Loss of C from rice biochar in alluvial soil without (left) and with (right) fertiliser.
Figure 2. Loss of C from wheat biochar in alluvial soil without (left) and with (right) fertiliser.

Keywords

Red soil, alluvial soil, biochar, CO2 respiration, mitigation

References

Soil management systems and how winter crops affect soil organic phosphorus cycle

Ademir Calegari*1, Tales Tiecher2, Danilo Rheinheimer dos Santos2, Marcos Antônio Bender2, Rogério Piccin2, Elci Gubiani2, Roque Junior Sartori Bellinaso2, Carlos Alberto Casali2

1 Soil Area, Agronomic Institute of Paraná, Londrina, Paraná State, Brazil
2 Department of Soil Science, Universidade Federal de Santa Maria, Brazil

*Corresponding author : calegari@iapar.br

The transformation of natural ecosystems into fields alters the distribution of the forms of phosphorus (P) in the soil, mainly the organic forms. Soil conservation systems, such as no-tillage (NT), in general are characterised by a higher total organic carbon (TOC) and total P content in the surface soil than under conventional tillage (CT) (Bolliger et al. 2006, Calegari et al. 2008). This is due mainly to the minimum soil disturbance, which promotes P accumulation, and to the addition of carbon and P in crop residues over time. These conditions facilitate the transformation of inorganic P added as fertiliser into organic forms, increasing the importance of biological P reactions in the topsoil under NT. Moreover, the cultivation of different plant species changes the P dynamics in the soil, mainly through P recycling and mobilisation by crop residues and the colonisation of microbial mobilisers of P in the rhizosphere of succeeding crops (Horst et al. 2001). Therefore, plants with a high P recycling capacity growing during the fallow period or winter under CT may increase the presence of organic forms of P. To test this, we evaluated the distribution of soil organic P forms, the P content in the soil microbial biomass (SMB) and the activity of acid phosphatase as affected by long periods with different winter species under different soil management systems.

A long-term experiment was established in 1986 at the Agronomic Institute Experimental Station at Pato Branco, south-western Paraná, Brazil (52°41’W, 26°07’S, 700 m a.s.l.). The soil at the site is an Oxisol (Rhodic Hapludox), very acidic with a high clay content (72%). The experimental area was covered by subtropical forest until 1976, when it was cleared, and was cultivated for 10 years by CT (1 disc ploughing + 2 disc harrowings). A field experiment was begun in the fallow period (winter) of 1986 to investigate the effect of soil tillage methods and winter fallow species. The experiment used a randomised block design with 3 blocks, 2 tillage treatments (CT and NT) and 5 winter fallow species -blue lupin (Lupinus angustifolius L.), hairy vetch (Vicia villosa Roth), black oat (Avena strigosa Schreb.), oilseed radish (Raphanus sativus L.) and winter wheat (Triticum aestivum L.) -plus bare fallow. Summer crops of soybean and maize were fertilised every year with the same total amount of nutrients in all treatments.
Soils samples were collected in October 2009 at five depths: 0–5, 5–10, 10–20, 20–30 and 30–40 cm. We determined the P content stored in the SMB, acid phosphatase activity, TOC, total P content and soil organic P forms by fractionation (Hedley et al. 1982).

The P stored in the SMB of the top 10 cm was higher under NT than under CT. The top 5 cm under NT had higher contents of organic P, total P and TOC and greater acid phosphatase activity than under CT. The top 5 cm had higher labile organic P under NT than under CT only in the crop succession involving oat, vetch, lupin and wheat. The total P content in the 10- to 30-cm layer under CT was 10% higher than under NT.

Regardless of soil management, the winter crops had greater P stored in the SMB than the bare fallow in all soil layers, mainly under lupin. Under NT, the cultivation of plants during winter increased the content of labile organic P (extracted by NaHCO₃) in the top 5 cm and the acid phosphatase activity in the top 10 cm. In the top 5 cm under NT, acid phosphatase activity was highest under vetch (1625 µg g⁻¹ h⁻¹), and the level of labile organic P was highest under black oat and blue lupin. Winter cropping also increased the TOC content in both soil tillage systems, especially in the top 10 cm.

Our results demonstrate that winter cropping in highly weathered subtropical soil increases the importance of microbial interactions in the P cycle, especially under NT, where a large amount of crop residues is added each year to the soil surface. These interactions reduce the sorption of inorganic phosphate by soil colloids, increasing soil organic P levels, the P content of the SMB and acid phosphatase activity. Therefore, growing winter crop species in rotation with summer crops, especially under NT, reduces the demand for phosphate fertilisers and promotes sustainable agriculture.

Keywords

No-tillage, cover crops, crop rotation, organic phosphorus, tropical soil

References


Diversity and structure of soil macrofauna communities under plant cover in a no-till system in Cambodia

Stéphane Boulakia¹, Lucien Seguy², Phakphoom Tantachasatid³, Sornprach Thanisawanyankura⁴, Vira Leng⁵, Johnny Boyer*⁶

1 CIRAD, UPR Système Ingénierie Agronomique, Cambodia
2 CIRAD, UPR Système Ingénierie Agronomique, Brazil
3 Kasetsart University, Sakon Nakhon campus, Thailand
4 Kasetsart University, Bangkok, Thailand
5 Ministry of Agriculture Forestry and Fisheries, Cambodia
6 CIRAD, UPR Système Ingénierie Agronomique, Thailand

*Corresponding author: johnny.boyer@cirad.fr

No-tillage soil cultivation generally enhances the abundance of organisms in the soil, especially microorganisms. Few studies have considered the effects of plant cover on soil macrofauna, or the functional role of plant cover in the biological function of soil (Marasas et al. 2001, Brown et al. 2002). Several studies have postulated that the density and diversity of the soil macrofauna, in addition to the presence of certain groups, may be used as soil quality bioindicators (Paoletti 1999). Soil macrofauna communities respond to human modifications of the environment. These responses are closely related to the types of plant cover, which in turn directly influence the amount and quality of soil organic components. The abundance and diversity of the soil macrofauna is therefore an important factor in the sustainability of primary production by natural and agricultural ecosystems (Decaëns et al. 2001).

The study of soil invertebrate communities, and more specifically of the macrofauna associated with various types of plant cover, could generate further information on the roles played by these different communities in supporting and improving soil fertility under cover crops. Similarly, the description of soil macrofauna communities associated with different types of plant cover, and of their changes over time, could contribute to the definition of soil status indicators.

We sampled macrofauna in August 2007 at the Bos Khnor seed station (Kampong Cham Province, Chamcar Loeu district), in eastern-central Cambodia (12°12’N, 105°19’E). The mean annual rainfall is 1500 mm, concentrated mainly from April to October, and the mean annual temperature is 27.5 °C. The sampling method used was that recommended by the Tropical Soil Biology and Fertility Programme (Lavelle and Pashanasi 1989, Anderson and Ingram 1993). In each agronomic system studied, 10 soil monoliths (25 cm × 25 cm × 30 cm) were collected at 6-m intervals, along a line whose origin and direction were randomly determined.
After removal of the litter, the monolith was cut into three successive 10-cm-thick layers. Any invertebrates visible to the naked eye were collected and fixed in 70% alcohol. The organisms were identified (Oligochaeta, Coleoptera larvae, Diptera larvae, Lepidoptera larvae, Formicidae, Diplopoda, Chilopoda, Isopoda, Isoptera, Araneidae, Coleoptera, Diptera, Dictyoptera, Heteroptera, Dermaptera, Gastropoda, Orthoptera, and “other”), counted and weighed in the laboratory.

The cover plants were sown in 2006 or 2007 on previously tilled plots. Macrofauna were collected in 2007 (1 month after sowing of maize) where the plant covers had been desiccated by herbicide sprays. We compared conventional tillage (CT: bare soil tilled with disc harrows and herbicide) with 4 direct-sown no-tillage systems under plant cover:

1) *Stylosanthes guianensis*, a long-cycle legume, sown in 2006.
2) *Brachiaria ruziziensis*, a long-cycle grass, sown in 2006.
3) *B. ruziziensis* + *Cajanus cajan* (legume), sown in 2006.
4) *Eleusine coracana*, a short-cycle grass, sown at the start of the rainy season in April 2007.

The area of each plot was 750 m².

All plots showed significant increases (Kruskal–Wallis test at 5%) in mean soil macrofauna density and biomass compared with CT: 395–766 m⁻² vs. 282 m⁻²; and 10.99–62.86 g m⁻² vs. 0.848 g m⁻². All diversity indicators (Margalef, Shannon–Wiener, Simpson and Hill) also showed significantly greater diversity (Kruskal–Wallis test at 5%) than in CT. In the presence of plant cover, the diversity, abundance and biomass of the soil macrofauna are rapidly restored.

**Keywords**

Plant cover, macrofauna, diversity, density, biomass

**References**


Recovery of soil macrofauna diversity through organic fertility patches: consequences for soil erosion in the uplands of northern Vietnam

P. Jouquet*,1,2, T. Doan Thu1, T. Henry-Des-Tureaux1, D. Orange1, J.L. Janeau1, T. Tran Duc1

1 IRD – SFRI, Tu Liem, Hanoi, Vietnam
2 IRD, UMR 211 BIOEMCO, Centre IRD Ile de France, Bondy, France

*Corresponding author: pascal.jouquet@ird.fr

The loss of soil biodiversity is a serious threat to sustainable agricultural land use. A practice known as zai technology is used in the West African Sahel to manage and rehabilitate degraded soils in dryland ecosystems. The practice consists of incorporating organic matter into pits, which increases activity by macrofauna and improves soil fertility (Roose & Barthès 2001). The aim of this study was to test zai technology in soil degraded by water erosion in northern Vietnam for the recovery of the diversity and activity of soil macrofauna (invertebrates 2–20 mm) and of underlying ecosystem services.

Field experiments were carried out in an experimental catchment (46 ha) of the MSEC (Management of Soil Erosion Consortium, IRD) project. Maize was grown in 4 fields, each of which received the same amounts of fertilisers. Each field was divided into 3 equal-sized plots separated by at least 2 m from each other. Patches of fertility were created every 1 m between the rows of maize. Three treatments were tested: 20 Mg ha−1 of dry compost applied in patches ~10 cm in diameter and 10–20 cm deep; compost plus 3 kg of dried cassava stems on top of the soil; and mineral fertiliser (N as 1.65 g CH4N2O, 0.38 g P2O5 and 1.47 g K2O) in equivalent patches. To investigate water runoff and soil erosion, we built three 1-m² microplots in each field (1 per treatment), in which surface runoff and detached sediments were collected after each rainfall event in a collector at the base of the microplot.

The soil macrofauna were able to locate and proliferate in the organic patches (Fig. 1). In particular, earthworms, termites, millipedes and ants proliferated, all of which are described as soil engineers in relation to soil organic matter and soil properties (Lavelle et al. 1997; Jouquet et al. 2006). A local decrease in soil density was evident. However, maize growth and yield did not correlate with this local improvement in soil quality, probably because the maize did not have access to the nutrients in the patch. In addition, these patches did not have a positive effect on water infiltration and soil erosion. In other words, although it is clear that conservation agriculture practices favour the proliferation of soil biota, whether this proliferation can then play a significant role in the recovery of soil fertility on sloping lands remains to be seen.
Figure 1. Soil macrofauna abundance (number of individuals per sample) outside (white) and inside (black) the patches of fertility.

TSBF = Tropical Soil Biology and Fertility Institute (sampling method). Histograms with the same letters are not significantly different at $P = 0.05$ ($n = 4$).

Keywords

Heterogeneity, organic matter, soil biodiversity, maize, zai technology

References


Conserving biodiversity and ensuring food security is a tough challenge. Creating a balance between food production and biodiversity conservation requires critical decisions and strategies. In the case of Agusan Marsh, Mindanao, the Philippines, studies of how biodiversity can be conserved and what environmental services the marsh provides for the community are needed.

The aim of this study was to describe how the aquatic insect diversity in major natural habitats of Agusan Marsh floodplain relates with that in nearby rice fields to determine the interdependence between the habitats in sustainable rice production. To assess the role of aquatic insects that migrate from their natural habitats in rice pest management, I sampled the diversity of predatory aquatic insect species in Agusan Marsh and adjoining rice fields each month and assessed the similarity of species composition. The study also illustrates the general role of aquatic insects in providing food to the early colonizing predators in rice fields and the contribution of herbivorous and scavenging Hydrophilidae (beetles) and Corixidae (bugs) in hastening the decomposition of organic matter.

Several species of aquatic insects from the natural habitats of Agusan Marsh (particularly from the Terminalia forest and sedge-dominated swamps) move into rice fields. An overwhelming majority of aquatic insects move between the habitats. Examples of these insects are Copelatus, Hyphydrus, Hydroglyphus and Laccophilus (Coleoptera: Dytiscidae); Anacaena, Berosus, Enochrus and Helocharis (Coleoptera: Hydrophilidae); Agriocnemis femina and A. pygmaea (Odonata: Coenagrionidae); Diplacodes trivialis, Neurothemis sp. and Tholymis tillarga (Odonata: Libellulidae); and the bugs (Hemiptera) Anisops sp. (Notonectidae), Tenagognathus robustus (Gerridae), Diplonychus rusticus (Belostomatidae), Microvelia douglasi atrolineata (Veliidae) and Micronecta quadristrigata (Corixidae). Commonality of species was more apparent during the dry season, when the flooded rice fields provide an alternative habitat for aquatic insects. In the rice fields, the insects promote rice production through increasing the organic matter by feeding and scavenging, providing food to early colonizing predators or reducing pest populations. The similarity of species composition between the habitats indicates that rice fields provide a corridor for habitat connectivity.
The findings of this study suggest that agriculture can provide corridors that interconnect patchy habitats. Managing the corridors by providing habitats favourable to the biodiversity that helps enrich the soil and provide natural control of pests can reduce the use of synthetic fertilisers and pesticides. This approach can make rice farming more environmentally friendly and ecologically sound, improving agricultural sustainability.

**Keywords**

Aquatic biodiversity, corridor, habitat connectivity, Philippines

**Bibliography**


Zettel H. 2001. The true aquatic bugs (Nepomorpha), the semiaquatic bugs (Gerromorpha), and the shore bugs (Leptopodomorpha) (Insecta: Heteroptera) of the Philippine islands: identification keys to families and genera, and notes on morphology, natural history, species diversity, and distribution. Training Manual, ViSCA, Leyte, Philippines.
Farmer-friendly erosion control measures in maize-based systems of the northern mountainous region of Vietnam

Gunnar Kirchhof*1, Nguyen Hoang Phuong2, Trinh Duy Nam3, Oleg Nicetic4

1 School of Agriculture and Food Sciences – St Lucia Campus, University of Queensland, Brisbane, Qld 4072, Australia
2 Faculty of Agronomy and Forestry, North West University, Son La, Vietnam
3 Northern Mountainous Agriculture and Forestry Science Institute, Tai Bac Centre, Son La, Vietnam
4 Centre for Communication and Social Change, School for Journalism and Communication, University of Queensland, Brisbane Qld 4072

*Corresponding author: g.kirchhof1@uq.edu.au

We evaluated soil erosion rates in farmers’ fields to assess when erosion occurs during the maize season and to identify which soil management practices best reduce erosion. We used a modified profile meter method to monitor erosion (Hudson 1993). Unlike Wischmeier plots, this method has minimum impact on farm operations. In brief, it monitors the drop in soil surface level below fixed reference points, which are steel pegs (pins) driven into the soil: the distance between the top of the peg and the soil surface is measured following a rainfall event. We inserted 4 pegs into the ground to ~40 cm in a 70-cm x 100-cm rectangle and monitored the distance at 8 constant locations within this erosion station. Measurement errors using this method can be large, owing to slumping of soils after tillage and to soil swelling. We compensated by taking a large number of measurements, monitoring soil bulk density to account for slumping, and assuming negligible shrink–swell on these 1:1-type clay soils. Although slumping occurred, it happened very quickly after tillage following rainfall; once the maize was sown, slumping was no longer observed.

The research comprised two phases: collection of baseline date on erosion; and monitoring soil erosion in field experiments in two communes, Na Ot (Son La) and La Nga (Moc Chau). The field trials used a randomised complete design with 4 blocks. Each plot had 2 erosion monitoring stations, and erosion was measured 8 times during the maize season at Na Ot and 10 times at La Nga. Slopes were ~25°. We also measured rainfall intensity, final maize yield, bulk density and single-ring infiltration rate. Following discussion with farmers, treatments were adjusted to what the farmers though they may use in future. The soil at both sites was cultivated with a hand hoe.

There were 4 treatments at La Nga: minimum cultivation with residues retained; cultivation with residues retained; cultivation with residues retained plus additional mulch; and cultivation with residues retained and rice bean (Vigna unguiculata) intercropping. No burning took place.
The quantities of residue retained ranged from 1 to 3 Mg/ha, and those of additional mulch ranged from 3 to 5 Mg/ha.

There were 4 treatments at Na Ot: slash and burn; cultivation with residues retained; residues retained and mini-terraces; and minimum cultivation with residues retained.

The quantities of residue retained averaged 4.3 Mg/ha with an average ground coverage of 83% before land preparation. The difference in residues between the two sites is due to grazing during the dry season.

For the baseline study, erosion was monitored in fields of 5 villages from late July to mid October on 5 dates. These villages are located in different communes in 4 provinces (Mai Sơn, Moc Chau, Sin Ho, Tam Đường). Erosion stations were located on slopes of between 20º and 30º on slope lengths longer than 100 m. The 68 erosion stations were distributed unevenly between fields, as we depended on access and farmer support to take measurements. Average soil loss ranged from 8 to 15 Mg/ha during that time, and there were no significant differences between provinces, communes or fields. We attributed these low erosion rates to the late onset of the monitoring schedule: the maize was well established and provided effective erosion protection by reducing raindrop impact. Visual assessment of erosion showed that most erosion occurs during the early phase of the growing season while the soil is unprotected.

During the 2011 maize season, average erosion at La Nga was 38 Mg/ha, with a very large variation (3–95 Mg/ha), but there were no significant differences between treatments, and it was not possible to differentiate between erosion rates at the start and towards the end of the season. We attributed the lack of significant differences to the retention of residues in all treatments and to the inherent variability of the measurement method we used.

Total erosion rates were much higher at Na Ot, and segmental regression showed a significant difference between the start and the end of the maize season. Most erosion occurred by 7 July 2011. The first measurement was taken on 22 April, and maize was sown on 11 May. This suggests that a large proportion of soil loss follows land preparation, before the maize is planted, and is aggravated by weeding (Podwojewski et al. 2008). Initial soil loss was 226 Mg/ha in the slash and burn treatment. There were no significant differences between the other treatments, in which residue was maintained; the average initial soil loss was 101 Mg/ha. The difference between residue burnt and residue maintained was significant at the 5% level. The average soil loss rate after 7 July 2011 was 17 Mg/ha (5–25 Mg/ha), and there were no significant differences between treatments.

The results show that most soil erosion occurs within the first 2 months of the cropping season, and the main factor in reducing erosion is the maintenance of ground cover. Therefore, the best way to reduce erosion is to encourage farmers not to burn, but to maintain crop residues.
Keywords

Soil erosion, participatory research, Zea mays, conservation agriculture, residue retention

References


Erosion on steep and fragmented lands: mitigation potential of soil conservation for maize cropping in north-western Vietnam

Tuan Vu Dinh*1,3, Thomas Hilger*1, Erisa Shiraishi1, Gerhard Clemens1, Lee MacDonald2, Georg Cadisch1

1 Institute of Plant Production and Agroecology in the Tropics and Subtropics, University of Hohenheim, 13 Garbenstrasse, 70599 Stuttgart, Germany
2 Department of Forest, Rangeland, and Watershed Stewardship, Warner College of Natural Resources, Colorado State University, Fort Collins, CO 80523-1472, USA
3 Institute for Agricultural Environment, Vietnam Academy of Agricultural Sciences, Phu Do, Me Tri, Tu Liem, Hanoi, Viet Nam

*Corresponding author: thomas.hilger@uni-hohenheim.de; vudinhtuan2001@yahoo.com

The area devoted to maize production in north-western Vietnam has increased greatly since the mid 1990s, mainly by expanding crop production into forested uplands. After slashing and burning, the farmers usually plough their fields during the dry season. At the onset of the monsoon rains, the tilled fields are bare, and the heavy rains cause severe erosion and longer-term degradation. This poses a serious threat to the sustainability of crop production in these areas. This hazard may be accelerated by the ongoing shift to growing maize for biofuels. Despite these severe threats to the environment, past soil and water conservation projects had only limited impact. Suggested technologies were not adopted for various reasons, such as being economically unattractive, increased labour requirements and failure to meet farmers’ needs. This study quantified the benefits of soil conservation in terms of soil cover, soil loss and maize yields in order to foster their adoption by local farmers.

The study was carried out in two catchments in the Son La Province, north-western Vietnam: Chieng Khoi and Chieng Hac. In 2009, sets of Wischmeier plots were installed at both sites in a randomised complete block design with 3 replicates. Plots were 18 m long and 4 m wide. The slope range was 59% ± 1% at Chieng Khoi and 53% ± 1% at Chieng Hac. The treatments were maize under farmers’ practice (control), maize with Panicum maximum grass barriers, maize under minimum tillage with Arachis pintoi as a cover crop, and maize relay-cropped with Phaseolus calcaratus. These treatments were selected as a result of discussions during a participatory workshop with farmers, the local extension service and researchers. For all treatments the fertiliser application rate was 158 kg N, 17.5 kg P and 58.6 kg K per hectare. Annual rainfall from 2009 to 2011 was respectively 930, 1305 and 1529 mm in Chieng Hac, and 1035, 1488, and 1299 mm in Chieng Khoi.
At Chieng Khoi, sets of sediment fences also were used to measure soil loss from 6 convergent unbounded maize fields under farmers’ practice in 2010 and 2011. Plot areas ranged from 420 to 1590 m², slope lengths were 25 to 47 m, and the slope gradients ranged from 27% to 74%.

To the extent possible, soil loss was measured after each storm. In the Wischmeier plots, soil cover was monitored in the first 2 years at 88 to 100 points using a transect method (modified after Benavides-Solorio 2001). In the third year, soil cover was determined by taking digital photos 3.5 m above the ground. These images were assessed by SamplePoint software (ARS-USDA 2011). Comparisons of both methods at 4 Wischmeier plots in Chieng Khoi showed no significant difference between the results of these 2 methods (P ≤ 0.05). The effect of the soil conservation measures on soil loss, yields and aboveground biomass was assessed by the PROC MIXED model in SAS 9.0 software. The Wischmeier plot was used as a random effect, and data were square-root-transformed to make the distribution normal. The LSMEANS software was used to calculate the significance of differences between the treatments (P < 0.05).

The soil loss from the unbounded plots was 18–111 Mg ha⁻¹ in 2010 and 10–55 Mg ha⁻¹ in 2011. Soil loss increased with slope length and gradient. The lower soil loss in the second year can be attributed to the difference in rainstorms with >25 mm: 20 in 2010 but only 14 in 2011.

The results from the farmers’ practice treatment (control) in the Wischmeier plot experiment showed that most of the erosion occurred in the first few weeks after sowing, when high rainfall intensities coincided with low soil cover. After juvenile growth, the maize cover greatly reduced soil loss. At both sites there was a highly significant (P < 0.001) negative exponential relation between coverage and storm-based soil loss (Chieng Hac, R² = 0.47; Chieng Khoi, R² = 0.50). We estimated that a ground cover of 70% to 85% is needed to reduce soil loss to below a tolerable level of 3 Mg ha⁻¹. In the first year (2009), soil loss did not differ significantly among treatments; values ranged from 2.6 to 7.0 Mg ha⁻¹ in Chieng Hac, and from 25 to 42 Mg ha⁻¹ in Chieng Khoi. In 2010, the measured soil loss under the control plots was 87 ± 13 Mg ha⁻¹ at Chieng Hac and 174 ± 27 Mg ha⁻¹ at Chieng Khoi. In 2011, soil losses from the controls dropped to 37 ± 8 Mg ha⁻¹ at Chieng Hac and 120 ± 8 Mg ha⁻¹ at Chieng Khoi.

Soil conservation measures had a significant (P < 0.001) impact on soil loss from the second year onwards. Well established grass barriers greatly reduced soil loss (Chieng Hac, 60%–84%; Chieng Khoi, 39%–48%) relative to farmers’ practice, and also provided fodder for ruminants, but maize yields decreased significantly by 18% to 36% compared with the controls. This reduction was greater when dry periods occurred during sensitive maize growth stages, as observed in 2010. On the other hand, grass production was 24% to 31% higher in 2010 than in 2011, which had a more even rainfall distribution. This shows that the P. maximum performed well under dry conditions and might increase farmers’ acceptance, because it mitigates the risks associated with erratic rainfall patterns.
Minimum tillage with either simultaneous or relay cropping of cover crops strongly reduced soil loss compared with farmers’ practice. Established cover crops significantly reduced maize yields owing to competition if pruning was not done in time. But a cut-and-carry system based on *Arachis pintoi* provided 3.3 Mg ha\(^{-1}\) of protein-rich fodder. These results show that careful management of cover crops is needed to minimise competition for water, nutrients and light.

The most promising option was maize under minimum tillage with relay cropping. In this treatment, maize yields reached the same level as the controls, and 1.2 Mg ha\(^{-1}\) of *P. calcaratus* beans were produced at Chieng Hac, while soil loss was reduced by 94%. This additional crop, when combined with the reduction in soil erosion, may make the farmers more willing to adopt soil conservation techniques.

**Keywords**

Minimum tillage, cover crops, soil loss, soil cover, relay cropping

**References**


No-till mulch-based maize cropping on sloping lands in northern Vietnam reduces soil loss and surface runoff

Tran Sy Hai*1, Didier Orange*2, Tran Duc Toan*1, Pham Dinh Rinh1, Dorian Decraene2, Delphine Zemp2, Nguyen Duy Phuong1, Jean-Louis Janeau2, Pascal Jouquet2, Christian Valentin2

1 Soils and Fertilizers Research Institute, VAAS, MARD, Hanoi, Vietnam
2 IRD, UMR211-BIOEMCO, University of Paris 6, France; posted at SFRI, Hanoi, Vietnam

Corresponding authors:
transyhai@gmail.com, didier.orange@ird.fr, toantransfri@gmail.com

In the Dong Cao experimental catchment in Tien Xuan Commune, Thach That, Hanoi District (Podwojewski et al. 2008; Valentin et al. 2008), we compared ‘dead mulch/no-tillage’ (DMNT) and farmers’ traditional (FT) systems of maize cropping on sloping lands. The experiment was funded by the PAMPA/RIME project of l’Agence Française de Développement. The objective was to measure surface runoff and soil loss at the field scale and the microplot scale (Janeau et al. 2003; Phan et al. 2012).

Two fields (600 m² for FT and 1400 m² for DMNT) were each equipped with a concrete sediment trap at their foot slope to collect eroded soil and surface runoff after each rain event. In each field we set 3 erosion plots of 1 m² each to measure soil loss and surface runoff.

In the DMNT field, maize was planted 5 cm deep directly through mulch composed of rice straw and weeds equating to 5 Mg/ha of dry matter. In the FT field, the farmer tilled the soil to a depth of 10–15 cm, piled the weeds and then burned them.

Maize was planted in both fields along the contour (70 cm between rows, 30 cm between plants). The crops received 120 kg N, 52 kg P and 75 kg K/ha in 2010 and 2011, and 100 kg N, 44 kg P and 75 kg K/ha in 2012 (to reduce the quantity of weeds regrowing).

Compared with the 10-year average rainfall (975 mm), the rainfall during the cropping season (April to August) was very low in 2010 (660 mm), very high in 2011 (1310 mm; >25% above the average) and average in 2012 (at 1060 mm) (Bernard-Jannin et al. 2011). The soil moisture was measured monthly at three points in each field, the soil compaction twice a year (before and after the rainy season) and the soil loss and surface runoff after each rainfall event. Soil loss is the sum of the bed load (the quantity of sediment collected inside the sediment trap) and the suspended load exported by the surface runoff, adjusted for area (Valentin et al. 2008).

Soil moisture was always greater under DMNT, mainly at the beginning of the cropping season in May (by 10% to 100% of FT).
In August, just before harvest, the increase was only 3% to 6%. After 3 years, the resistance to shear strength, which reflects the resistance to rill and gully erosion, was slightly higher in DMNT (3.46 ± 0.84 kg/cm²) than in FT (2.79 ± 0.99 kg/cm²), possibly because annual tillage in FT loosens the soil. This difference shows that interpreting results from DMNT should include not only changes in organic matter content and faunal activity, but also changes in soil physics.

In the microscale plots, surface runoff was greater under DMNT (5 L/m²/y) than under FT (2 L/m²/y) (Fig. 1). Soil loss was similar between the two systems (0.8 g/m²/y; Fig. 2), implying more effective erosion under FT than under DMNT.

Figure 1. Mean annual surface runoff (L/m²/y) on 1-m² erosion plots under farmers’ traditional system (FT) and dead mulch/no-tillage system (DMNT).

Figure 2. Mean annual soil loss (g/m²/y) on 1-m² erosion plots under farmers’ traditional system (FT) and dead mulch/no-tillage system (DMNT).
Since soil moisture and soil compaction were greater under DMNT, we assume that soil saturation was reached faster under DMNT, which is why runoff was greater at the micro-scale than at the field scale, but this surface water was less erosive under DMNT.

At the field scale, soil loss was much greater under FT than under DMNT (Table 1), at >140 Mg/ha in 2010 and 2011 (The very low soil loss in 2012 was due to the absence of rain in April).

Table 1. Soil and nutrient losses under farmers’ traditional system (FT) and dead much/no-tillage system (DMNT).

<table>
<thead>
<tr>
<th>Terms</th>
<th>2010</th>
<th></th>
<th>2011</th>
<th></th>
<th>2012</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FT</td>
<td>DMNT</td>
<td>FT</td>
<td>DMNT</td>
<td>FT</td>
<td>DMNT</td>
</tr>
<tr>
<td>Soil loss (Mg/ha)</td>
<td>145.13</td>
<td>1.35</td>
<td>150.57</td>
<td>0.03</td>
<td>0.421</td>
<td>0.033</td>
</tr>
<tr>
<td>OC (kg/ha)</td>
<td>4266.8</td>
<td>42.7</td>
<td>4381.6</td>
<td>0</td>
<td>12.2</td>
<td>1.04</td>
</tr>
<tr>
<td>N (kg/ha)</td>
<td>333.8</td>
<td>3.0</td>
<td>316.2</td>
<td>0</td>
<td>0.9</td>
<td>0.07</td>
</tr>
<tr>
<td>P (kg/ha)</td>
<td>56.38</td>
<td>0.57</td>
<td>60.44</td>
<td>0</td>
<td>0.2</td>
<td>0.02</td>
</tr>
<tr>
<td>K (kg/ha)</td>
<td>204.8</td>
<td>2.5</td>
<td>237.5</td>
<td>0</td>
<td>0.7</td>
<td>0.08</td>
</tr>
</tbody>
</table>

We assume that the soil loss was highest in 2010 in spite of the weak rainfall because of the soil preparation in FT and the weeding of shrubs in DMNT. At the field scale, surface runoff was much less under DMNT than under FT, the opposite of the results at the micro-scale. The difference between scales is explained by the appearance of more gullies along the slopes in FT (0.165 m/m²) than under DMNT (0.102 m/m²).

At the catchment scale, we measured significant differences between export of suspended load and bed load. Under FT, bed load was responsible for >95% of the soil loss, whereas under DMNT, suspended load was responsible for nearly 100% of the loss. Nutrient loss with eroded sediment was higher under FT compared to DMNT.

Our results show that erosion is due largely to surface runoff in response to rainfall pattern. The differences in soil compaction and soil cover explain the greater sensitivity of the soil under FT to erosion. This local process is emphasised at the field scale by the appearance of gullies.

**Keywords**

Soil erosion, surface runoff, dead mulch no tillage
References


Bed planting improves productivity of winter wheat in irrigated areas of Azerbaijan

I. Jumshudov*1, A. Nurbekov2, H. Muminjanov3, A. Musaev4 and S. Safarli5

1 Azerbaijan Research Institute of Farming
2 ICARDA-CAC, Tashkent, Uzbekistan
3 FAO/SEC, Ankara, Turkey
4 Azerbaijan Agrarian Center, Baku, Azerbaijan
5 Azerbaijan Research Institute of Irrigation and Soil Erosion, Baku, Azerbaijan

*Corresponding author: imran_cumshudov@mail.ru

Azerbaijan has diverse agroecological and climatic conditions. Traditionally, agriculture is based on water-demanding crops, and water shortages occur during summer in many regions, including Ter-Ter district, where we conducted our experiment. Improving water efficiency through better irrigation and conservation agriculture technologies has become a crucial issue. With efficient management and the adoption of appropriate practices, improved water conservation and greater crop production are possible under both dryland and irrigated conditions, thus helping to meet the water needs of all users and providing food and fibre for the increasing global population (Unger and Howell 1999). Proper management could significantly increase water storage and, consequently, wheat grain yields (Bouaziz and Chekli 1999). The use of proper irrigation management could increase water use efficiency and reduce costs (Norwood and Dumler 2002; Fahong et al. 2004).

Bed planting systems for wheat cultivation are gaining importance in various environments worldwide. Bed planting is used under irrigated conditions in Azerbaijan, but the area is very low when compared with conventional planting practices. The introduction of bed planting in northern Mexico increased the grain yield of wheat by at least 10% while decreasing the water consumption by up to 35% (Aquino 1998). Similar results could be achieved in Azerbaijan.

The objective was to compare conventional planting and bed planting at 2 different sowing rates of winter wheat under irrigated conditions to identify the best combination to increase grain yield while decreasing water consumption.

The site is located on the Karabakh steppe in the southern subzone of the Ganja climatic region. The Kura-Araks lowlands are located between the Kura and Kar-Karchai rivers and the Minor Caucasus range. The mean rainfall during the cropping season ranges from 300 to 450 mm, and rain falls mostly in November–December and April–May. There is almost no rain from July to September. The climate is continental, with an average annual temperature of 14–15 °C. Summer temperatures reach 35 °C, with an absolute maximum of 40 °C.
The sum of effective temperature during the cropping period is 3585 °C. The water table is 3 to 10 m deep. The total dissolved salts content ranges from 1 to 10 mg L⁻¹. The soil is a grey-brown heavy loam with an organic matter content of 1.77% to 2.23% in the top 20 cm. The whole area is served by earthen canals providing surface irrigation.

The main benefit of bed planting is water saving. Almost all farmers reported 30% to 35% less irrigation time. In addition, bed planting gave higher yields under favourable conditions than flat-bed planting. Our results agree with those of Fahong et al. (2004) in China, who found an improvement in water use efficiency of 21% to 30% combined with a saving of ~17% in applied irrigation water. The water use efficiency was significantly higher with bed planting (2.36 and 2.11 kg m⁻³) than with conventional planting (1.67 and 1.85 kg m⁻³; Table 1). The grain yields were less conclusive: Farm 1 produced a significantly higher yield with bed planting, but Farm 2 showed a much smaller difference.

**Table 1.** Effects of traditional planting and bed planting on winter wheat yields and water use efficiency.

<table>
<thead>
<tr>
<th>Farm</th>
<th>Treatments</th>
<th>Yield (Mg ha⁻¹)</th>
<th>Water rate (m³ ha⁻¹)</th>
<th>Water use efficiency (kg m⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2011</td>
<td>2012</td>
<td></td>
</tr>
<tr>
<td>Farm 1</td>
<td>Traditional planting</td>
<td>3.76</td>
<td>3.54</td>
<td>1900</td>
</tr>
<tr>
<td></td>
<td>Bed planting</td>
<td>5.23</td>
<td>5.10</td>
<td>1600</td>
</tr>
<tr>
<td>Farm 2</td>
<td>Traditional planting</td>
<td>2.57</td>
<td>2.23</td>
<td>1950</td>
</tr>
<tr>
<td></td>
<td>Bed planting</td>
<td>3.42</td>
<td>3.52</td>
<td>1600</td>
</tr>
</tbody>
</table>

Bed planting produced the highest net benefit and profitability (Table 2). This could be critical in wet years, when the market price of wheat decreases with the greater abundance of grain on the market.

**Table 2.** Economics of planting methods on winter wheat productivity in Azerbaijan.

<table>
<thead>
<tr>
<th>Planting method and sowing rate</th>
<th>Grain yield (Mg ha⁻¹)</th>
<th>Production cost (USD ha⁻¹)</th>
<th>Production value (USD ha⁻¹)</th>
<th>Net benefit (USD)</th>
<th>Profitability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional 220 kg ha⁻¹</td>
<td>3.02</td>
<td>465</td>
<td>960</td>
<td>495</td>
<td>106</td>
</tr>
<tr>
<td>Bed 130 kg ha⁻¹</td>
<td>4.29</td>
<td>535</td>
<td>1280</td>
<td>745</td>
<td>139</td>
</tr>
</tbody>
</table>

Water use efficiency is important in Azerbaijan in view of the limited water resources there. Our results are only preliminary. More detailed study of the factors influencing farmers’ choices and preferences is required.
Keywords

Water use efficiency, seeding rate, grain yield

References


Conservation agriculture including cover crops and crop rotation can improve maize yield

Ademir Calegari*1, Antonio Costa1, Danilo Rheinheimer dos Santos2, Tales Tiecher2, Carlos Alberto Casali2

1 Soil Area, Agronomic Institute of Paraná, Londrina, Paraná State, Brazil
2 Department of Soil Science, Universidade Federal de Santa Maria, Brazil

*Corresponding author: calegari@iapar.br

Cropping systems in which nutrients are removed by crop harvesting and are not replaced are unsustainable. Historically, crop residues have played important roles as mulch for soil and water conservation and in maintaining soil organic matter and returning nutrients to soil (Basch et al. 2012). Studies carried out in Paraná state, Brazil, on clay soils showed that conservation farming systems such as no-till (NT) controlled soil degradation and enhanced soil chemical, physical and biological characteristics: more nutrients were made available by crop recycling, enhancing soil particle aggregation and water infiltration rates, fostering soil biology and giving higher yields than intensive tillage (IT) (Calegari et al. 2008).

The conversion of natural ecosystems into fields alters the soil organic carbon (SOC) and the distribution of nutrients in the soil. Soil conservation systems, such as NT, in general are characterised by a higher total organic carbon content and greater nutrient availability in the surface soil than under IT (Florentin et al. 2010). This is due mainly to minimum soil disturbance, the annual addition of crop residues and the build-up of SOC.

The purpose of this study was to demonstrate that rotating winter crops with summer crops can promote soil conservation, increase nutrient recycling during winter and possibly increase the summer crop yield. The adoption of conservation farming may be a rational way to reduce soil degradation, recover soil fertility, decrease production costs and improve yield (Prudencio et al. 2004). In Brazil, we estimate that more than 32 million ha under NT systems contributes to improved livelihoods for small-, medium- and large-scale farmers.

This study was designed to evaluate the effect of a long history of winter cropping under different soil management systems on summer crop yields as affected by cover crops and crop rotation under NT.

A long-term experiment was established in 1986 at the Agronomic Institute Experimental Station at Pato Branco, south-western Paraná, Brazil (52°41’W, 26°07’S, 700 m a.s.l.). Climatologically, the area belongs to the subhumid tropical zone, or Köppen’s Cfb (without dry season; with fresh summer; average of hottest month <22 °C). The annual rainfall averages 1200 to 1500 mm.
The soil of the experimental site is an Oxisol (Rhodic Hapludox), very acidic with a high clay content. The A horizon (0–1 m) consists of 72% clay, 14% silt and 14% sand. Its mineralogical composition is 68% silicate type 1:1 (kaolinite and halloysite), 13% silicate type 2:1 (vermiculite and/or montmorillonite), 14% iron oxides and 5% gibbsite. The iron oxide composition is 51% haematite, 36% goethite and 13% maghemite. The treatments combined winter cover crops with NT or IT. The winter cover crops were blue lupin (*Lupinus angustifolius* L.), hairy vetch (*Vicia villosa* Roth), common vetch (*Vicia sativa* L.), black oat (*Avena strigosa* Schreb), ryegrass (*Lolium multiflorum* L.), oilseed radish (*Raphanus sativus* L.), winter wheat (*Triticum aestivum* L.), rye (*Secale cereale* L.), lupin + oat, vetch + oat and fallow (no cover). Cover crops were controlled with a knife roller or herbicide. Maize and soybean were grown every summer. The treatments were laid out in a split-plot design in 3 blocks, with the winter cover crops as the main plots (240 m²) and the tillage treatments as the subplots (120 m²) to assess the effects on maize yield.

Across all winter cover crops, the maize grain yield in 2009 was significantly greater under NT (Table 1). Within cover crops, the yields were significantly greater under NT following white lupin + oat, common vetch, hairy vetch + black oat, black oat and blue lupin. The yield following common vetch under NT was significantly greater than those following wheat, ryegrass, rye and radish. The yields under IT were not significantly different among cover crops. The highest maize yield followed common vetch under NT (9.48 Mg ha⁻¹), and the lowest followed black oat under IT (7.00 Mg ha⁻¹). The results show that NT cultivation with some cover crops grown in rotation with maize can promote soil conservation, improve soil characteristics and enhance maize yields.

### Table 1. Maize grain yield (Mg ha⁻¹) after winter treatments, Pato Branco, Paraná, Brazil, 2009.

<table>
<thead>
<tr>
<th>Winter cover</th>
<th>No-tillage</th>
<th>Intensive tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hairy vetch</td>
<td>8814 ab A</td>
<td>7926 a A</td>
</tr>
<tr>
<td>Common vetch</td>
<td>9481 a A</td>
<td>8074 a B</td>
</tr>
<tr>
<td>Wheat</td>
<td>8055 bc A</td>
<td>8111 a A</td>
</tr>
<tr>
<td>Ryegrass</td>
<td>8555 bc A</td>
<td>8037 a A</td>
</tr>
<tr>
<td>Rye</td>
<td>7999 bc A</td>
<td>7536 a A</td>
</tr>
<tr>
<td>Radish</td>
<td>7462 c A</td>
<td>7222 a A</td>
</tr>
<tr>
<td>Black oat</td>
<td>8444 abc A</td>
<td>7000 a B</td>
</tr>
<tr>
<td>Blue lupin</td>
<td>9111 ab A</td>
<td>7500 a B</td>
</tr>
<tr>
<td>White lupin + oat</td>
<td>8888 ab A</td>
<td>7166 a B</td>
</tr>
<tr>
<td>Hairy vetch + black oat</td>
<td>9092 ab A</td>
<td>7055 a B</td>
</tr>
<tr>
<td>Fallow</td>
<td>8333 abc A</td>
<td>8036 a A</td>
</tr>
<tr>
<td><strong>Average</strong> 1</td>
<td><strong>8567 A</strong></td>
<td><strong>7606 B</strong></td>
</tr>
</tbody>
</table>

1 Means followed by the same small letter down rows or capital letter across columns are not significantly different by Tukey’s test at P = 0.05.

Keywords

No-tillage, soil conservation, cover crops, crop rotation, maize yield

References


Yield, biomass and soil quality of conservation agriculture systems in the Philippines

Agustin R. Mercado Jr*, Vic Ella2 and Manuel Reyes3

1 World Agroforestry Centre, Claveria, Misamis Oriental, the Philippines
2 University of the Philippines at Los Baños, Laguna 4031, the Philippines
3 North Carolina Agricultural and Technical State University, Greensboro, NC, USA

*Corresponding author: agustin9146@yahoo.com; amercado@yahoo.com

Land degradation due to rapid soil erosion and nutrient removal in crops is expanding rapidly in the Philippines (Garrity 2003). Decreased agricultural productivity in turn worsens food insecurity and poverty, particularly on sloping acidic uplands on which the soils are inherently poor (Mercado 2007). We felt that conservation agriculture (CA) could offer a solution to this pressing problem.

Our objective was to assess the feasibility of a set of alternative cropping systems based on CA principles to enhance production while protecting natural capital. We compared 5 alternative CA treatments with conventional maize tillage (Table 1).

Table 1. CA treatments trialled in Claveria, Misamis Oriental, the Philippines.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize + Arachis pintoi</td>
<td>Maize seeds were dibble-planted at a spacing of 70 cm x 20 cm (71 000 plants/ha). Arachis pintoi cuttings were planted in a single row in the middle of maize rows every 25 m. In subsequent maize crops, fertiliser was applied, and seeds were planted in furrows in the living Arachis mulch.</td>
</tr>
<tr>
<td>Maize + Stylosanthes / Stylosanthes fallow</td>
<td>The maize was established and managed as for maize + Arachis. Stylosanthes guianensis seeds were drilled between rows of maize and thinned to 10–15 plants/m. In subsequent crops, the stylo was flattened and sprayed with glyphosate before maize planting.</td>
</tr>
<tr>
<td>Maize + cowpea / upland rice + cowpea</td>
<td>The maize was established in double rows spaced 35 cm apart at 20 cm between plants (72 000 plants/ha), followed by 2 rows of cowpea spaced 35 cm apart at 10–15 plants/m. After the cowpea harvest, upland rice was planted. After the maize harvest, cowpea was planted.</td>
</tr>
<tr>
<td>Maize + rice bean</td>
<td>Rice bean was established first. Two weeks later, maize was established as for maize + Arachis. During subsequent crops, rice beans and weeds were sprayed with glyphosate before maize planting.</td>
</tr>
<tr>
<td>Cassava + Stylosanthes</td>
<td>Furrows were spaced at 100 cm and cassava cuttings were planted 50 cm apart (20 000 plants/ha). S. guianensis seeds were drilled between rows of cassava and thinned to 10–15/m. During subsequent crops, the stylo was flattened and sprayed with glyphosate before the cassava was planted.</td>
</tr>
<tr>
<td>Maize / maize (conventional plough based)</td>
<td>Two ploughings by animal-drawn mouldboard plough; two harrowings by animal-drawn spike-toothed harrow; furrowed by animal-drawn mouldboard plough.</td>
</tr>
</tbody>
</table>

A trial was set up on a farm in Claveria, Misamis, the Philippines (8°38’39”, 124°55’49”), on land with a slope of 26%. 
The treatments were tested with 2 levels of fertiliser: low (F1; N–P–K = 0–13–0) and moderate (F2; 60–13–25). F1 was changed in the following year to 120–20–25 owing to the very poor performance of the crops during the first year. This level of fertiliser proved to be optimum. Fertiliser levels were laid out perpendicular to all treatments, giving a strip plot design with 4 replicates and a plot size of 10 m x 20 m (200 m²).

We recorded grain yield, tuber yield and aerial biomass of both the commercial crops and cover plants in 2010 and 2011. Soil was also sampled at 3 depths (0–5, 5–15 and 15–30 cm) in 2010, 2011 and 2012 for the analysis of bulk density, soil organic matter, soil N, soil P and soil pH. The residual soil moisture content was measured by time domain reflectometry.

In 2010, monoculture maize had the highest grain and biomass yields among the maize-based systems (Table 1), but these were superseded by other treatments in 2011, particularly when the fertiliser rate was increased. Grain and biomass yields improved in the CA treatments in 2012.

Omitting N, P and K respectively reduced maize yields by 67%, 59% and 21%. The optimum rate of NPK application for maize was 120–8–0, but the maintenance application of K at 17 kg/ha was necessary to avoid K soil mining by the crop. We identified promising cultivars of maize, upland rice, cowpea, forage grasses, forage legumes, sweet potato, cassava and sorghum, which out-yielded locally grown cultivars in grain and stover yields.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Yield (t/ha)</th>
<th>Biomass (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010 F1 F2 F1 F2</td>
<td>2010 F1 F2 F1 F2</td>
</tr>
<tr>
<td>Maize + Arachis pintoi</td>
<td>1.03bc 2.12bc 5.52bc 2.74bc</td>
<td>4.92bc 8.12b 8.28b 3.36b</td>
</tr>
<tr>
<td>Maize + Stylosanthes / fallow</td>
<td>1.10b 2.22bc 4.82bc 4.65bc</td>
<td>4.02bc 8.22b 7.23b 6.97b</td>
</tr>
<tr>
<td>Maize + cowpea / upland rice + cowpea</td>
<td>0.75b 1.59cd 5.57cd 4.09cd</td>
<td>3.75cd 6.47b 8.35b 6.14b</td>
</tr>
<tr>
<td>Maize + rice bean</td>
<td>0.14b 0.45d 6.49d 5.32d</td>
<td>0.68d 1.67b 9.74b 7.97b</td>
</tr>
<tr>
<td>Cassava + Stylosanthes</td>
<td>13.94a 20.73a 29.71a 18.93a</td>
<td>20.78a 31.44a 42.47b 27.10a</td>
</tr>
<tr>
<td>Maize / maize</td>
<td>2.47b 3.19b 5.10b 4.73b</td>
<td>7.50b 11.38b 7.65b 7.00b</td>
</tr>
<tr>
<td>Mean</td>
<td>3.25 5.07 9.44 8.92</td>
<td>7.1 5.07 13.86 9.88</td>
</tr>
<tr>
<td>LSD</td>
<td>1.66 3.85 8.00 4.98</td>
<td>3.55 3.85 9.56 6.77</td>
</tr>
</tbody>
</table>

Means followed by the same letter within a column are not significantly different by LSD at 5%.

The results show variability in soil quality over time and with depth. The soil organic matter in the uppermost layer (0–5 cm) did not show a clear pattern of temporal variation in most of the treatments, although that under the conventional plough-based system appeared to decline slightly over time.
Both soil N and P concentrations in all treatments were generally higher in the upper soil (0–15 cm) than in the deeper soil (15–30 cm) under both fertiliser levels. The soil bulk density remained practically the same as the baseline in all soil layers. Analysis of variance of the residual moisture during the driest month showed that the plots under CA had significantly higher residual moisture than under the conventional system, with the maize + stylo treatment having the highest content.

Continuous grain, biomass and soil quality monitoring is necessary to generate additional empirical evidence of the impact of CA on upland crop production on sloping acidic uplands in the Philippines.

Cassava + stylo produced greater biomass across all CA treatments. Monoculture maize produced higher grain and biomass yield among the maize-based systems during the first year, but was superseded in the following year by the CA treatments. Soil quality did not change dramatically over this period. Our research provides new information on the suitability of crops and soil fertility management for integration into CA research in the Philippines.

Keywords

Intercropping, production systems

References


Technical efficiency of wheat production under different cropping systems in Nineveh province, Iraq: a stochastic frontier production function analysis

Mohammed Jabar Abdulradh*1,2, Malcolm K. Wegener2, and Kamel Shideed3

1 Maysan Directorate of Agriculture (Ministry of Agriculture), Maysan province, Iraq
2 University of Queensland, St Lucia, Queensland 4072, Australia
3 ICARDA, Aleppo, Syria

*Corresponding author:
mohammed.abdulradh@uqconnect.edu.au, m_j_a1973@yahoo.com

Meeting the global demand for food due to population growth, reducing the effects of intensive agriculture on the environment and adapting to climate change have contributed to expansion of the area under conservation agriculture (CA). Iraq, a region where conservation tillage practices might be appropriate, has been influenced by these factors as well. Ironically, while agriculture began in Iraq, it took Iraqi farmers 80 years to adopt zero-tillage practices: CA was introduced in 2006 in northern Iraq through an ICARDA project funded by the Australian government agencies AusAID and ACIAR. Wheat is the major crop grown in Iraq: under rainfed conditions in northern Iraq and under irrigation in central and southern Iraq. We measured the technical efficiency of production by 338 wheat farmers in Nineveh province, northern Iraq, using the stochastic frontier production function (SFPF) approach and compared the technical efficiency of zero-tillage and intensive tillage to investigate sources of inefficiency.

Data from a cross-section of farmers who grew wheat in the 2010–11 season were used. The questionnaire that was used to gather the data was designed by the Iraq–ICARDA–Australia project team. The survey, using a stratified sampling technique, was carried out in 4 districts. The zero-tillage extension program had been focused in the dryland farming areas. Because Tilkaif district has the highest rainfall among the districts, almost all the zero-tillage farms were located there.

Technical efficiency has been estimated by using many different approaches. The choice of approach depends on many factors, such as the kind of data available for the analysis, the aim of the research and researcher preferences (Wadud and White 2000, Resti 2000). Different methods can give different results. We used both Cobb–Douglas and translog production functions.

Parameter values for frontier production function models can be calculated by both parametric and non-parametric models. Parametric models rely on a specific functional form, and can be classified as deterministic and stochastic.
They differ in their sensitivity in estimating the importance of outliers to technical efficiency. The deterministic approach assumes that inefficiency causes deviations from the frontier.

This assumption creates a fundamental problem for the estimation of technical efficiency, because any error in measurement or any other cause of variation from the frontier is embedded in a one-sided error component that leads to a value sensitive to outliers (Greene 2008). Descriptions of parametric models with more detail can be found in Kumbhakar et al. (1999).

Non-parametric models differ from parametric models in that they do not need to specify a functional form. The data envelopment analysis approach tries to overcome several drawbacks of parametric models such as the sensitivity problem, number of observations required and frontier dimensions (Ramanathan 2003).

We chose the parametric (SFPF) approach, using multiple inputs to produce a single output in a wheat growing system in which the heterogeneity of agrarian society is a feature. We chose SFPF for its ability to relax the assumption of constant returns to scale, its mathematical form, and its ability to determine the efficiency of wheat production caused by several factors which are out of the farmer’s control.

The mean level of technical efficiency was 87% for zero-tillage farms and 75% under conventional tillage. This difference means that the adoption of zero-tillage farming could substantially increase the average yield of wheat.

The significant variables in the production function were irrigation methods, crop protection chemicals, fertilizer, seed quantity and improved cultivars. The variables having an effect on inefficiency among farmers were tillage method, family size and sowing date. In fact, zero-tillage farming was the main contributor to efficiency gains in wheat production in the study area.

We can make recommendations to improve wheat production in Iraq in general and in the north in particular. Reallocating government subsidies from agricultural inputs (such as fertilizers, pesticides and fuel) to support the supply of zero-tillage machinery, and providing incentives to farmers to adopt this technique, would be a better use of public funds. Such a policy would substantially improve the efficiency of resource use in wheat production in Iraq. The results consistently associated high levels of technical efficiency with the adoption of zero-tillage farming.

Fuel subsidies might be reallocated directly to encourage farmers to adopt zero-tillage farming, but fertiliser and pesticide subsidies might be reallocated step by step according to improvements in soil organic matter and biological protection due to the use of CA.

Keywords

Conservation agriculture; production functions; zero tillage
References


Vermi-compost to improve tomato production in Bangladesh

S. T. Hossain*, M. J. Uddin2 and H. Sugimoto3

1 Friends In Village Development Bangladesh, Dhaka, Bangladesh
2 Department of Soil, Water & Environment, University of Dhaka, Dhaka, Bangladesh
3 Laboratory of Crop Science, Faculty of Agriculture, Ehime University, Ehime, Japan

*Corresponding author: tanveer107@yahoo.com

Our objective was to test the effectiveness of vermi-compost as a substitute for inorganic fertilisers for sustainable, large-scale tomato production. The Green Revolution in Bangladesh promoted the indiscriminate use of factory fertilisers and pesticides to obtain better crop yields. Owing to poor soil management, the organic matter (OM) content is decreasing in some situations. The use of organic fertilisers along with effective soil management can restore soil OM and sustain soil health. Vermi-compost (VC) - mainly the excreta of earthworms - is rich in humus and nutrients. It also contains a lot of microorganisms beneficial to plant growth. As a soil amendment, VC may provide a tool for soil OM management.

During the last few years we have been promoting VC production in rural households and training farmers in its application. Usually the VC is used for homestead vegetable production. Large-scale farmers prefer factory fertiliser (FF). We undertook this study to assess the production and economic returns from the use of VC in large-scale tomato production. If VC can work effectively in large-scale production, farmers can produce VC at home and save on fertiliser costs, and reduce their dependency on FF, which is sometimes not available.

We compared VC with FF and cow dung (CD) on ‘Raja’ hybrid tomatoes. The treatments were arranged in a randomised complete block design with 3 replicates. The field experiments were undertaken in the Chiknagul Union under Jointapur upazila in Sylhet District of Bangladesh from November 2011 to February 2012. To generate the VC, the farmers added earthworms to CD; the VC was ready after 25–30 days. Twenty-five-day-old tomato seedlings were planted 40 cm apart in rows 60 cm apart. Each plot measured 600 m². VC was applied at 11.25 Mg ha⁻¹ three times: during land preparation, 15 days after planting and at flowering (Chanda et al. 2011).

We adjusted the rate of the CD and the FF (urea, triple superphosphate, KCl) to supply the same N as the VC (Chanda et al. 2011). The FF comprised 600 kg urea ha⁻¹, 450 kg superphosphate ha⁻¹ and 250 kg KCl ha⁻¹ (Hussain et al. 2006). Two-thirds of the urea and all of the superphosphate and KCl were applied during land preparation, and the rest of the urea was applied 15 days after planting.
The CD was applied at 16 Mg ha\(^{-1}\) 3 times: during land preparation, 15 days after planting and at flowering. The dried CD was incorporated into the soil by hand hoe. The VC contained 2.2% N, 1.3% P, 2.4% K, 0.9% Ca, 0.18% Mg and 0.44% S. The CD contained 1.2% N, 1.0% P, 1.6% K, 0.13% S and 48.6% OM.

Pheromone traps were used for insect control. To control tomato wilt (a few symptoms of which were seen in the FF plots), 10% cow’s urine was sprayed 3 times 10 days apart. Harvesting began on 13 January 2012. Five plants of each treatment were selected randomly to measure the yield.

The plants responded much better to VC than to the other fertilisers. The VC- and CD-treated plants showed more branching than the FF-treated plants, but overall stem lengths were greater in the FF-treated plants. The yield was highest in VC plots. The number of tomatoes per plant averaged 51.8 in VC, 45.6 in FF and 45.8 in CD plots. The weight of each tomato averaged 73.0 g in VC, 69.3 g in FF and 67.7 g in CD plots. Twenty farmers were invited to taste the ripened tomatoes; 12 farmers preferred the VC-treated tomatoes, and 7 preferred the CD-treated tomatoes.

On the other hand, FF gave the highest economic benefit. Some VC was purchased from the market or from neighbouring farmers at 8–10 BDT (≈ 0.10–0.12 USD) kg\(^{-1}\). We assume that this cost can be reduced if the farmers produce their own VC, which we recommend. After the first year’s experiment, we analysed the top 10 cm of the soil: the VC-treated plots had higher contents of organic carbon (0.50%), OM (0.86%) and total N (0.030%) than the CD-treated plots (0.31%, 0.54%, 0.016%, respectively). The C/N ratio was higher in CD (19.8), followed by VC (17.0) and FF (16.0). This indicates that the VC and CD treatments stabilise the soil and sequester carbon quickly.

These results show that VC can be used as an alternative to FF and can improve the fertility of the soil, enhancing the growth and yield of the tomato crop.

**Keywords**

Natural resource, nutrient management, livelihood, soil health, worm compost

**References**


Potential of minimum-tilled maize + legumes for double cropping on high-elevation Acrisols in north-western Vietnam: a case study in Lai Chau province

Nguyen Phi Hung*1, S. L. Ranamukhaarachchi2

1 Mountainous Agriculture and Forestry Science Institute (NOMAFSI), Mai Son, Son La, Vietnam
2 Agricultural System and Engineering-Asian Institute of Technology, Bangkok, Thailand

*Corresponding author: hung_pfrc@yahoo.com

Sloping land accounts for 94% of the land area of the northern mountainous region of Vietnam, and more than half of this is steeper than 20° (Le 1997). The average biophysical conditions suggest that maize cropping would be possible from March to September: the average monthly rainfall is >50 mm and the average monthly temperature is >10 °C. However, most land-constrained farmers located above 700 m a.s.l. grow only 1 maize crop per year; they cite rainfall uncertainty, lack of appropriate cultivars and labour requirements as the main constraints to growing a second crop.

During a single cropping season we assessed the technical potential of intensifying agricultural production on high-elevation sloping land through growing a second crop. Our experiment was carried out in Ho Thau commune, Tam Duong district, Lai Chau province (22°20’N, 103°35”E), at 835 m a.s.l. The soil was an Acrisol with a slope of >40° (i.e. with no possibility of mechanization).

We compared yield components and soil losses between farmer practice (1 tilled maize crop per year) and double cropping (1 tilled maize crop followed by a minimum-tilled second crop). We tested 7 second crops: a sole maize crop (46 200 plants/ha, single rows 70 cm apart), a sole legume crop (277 800 plants/ha; soybean, black bean or peanut; Hoang 1993), and intercropping of maize with each legume. In intercropping, maize was grown in pairs of rows (35 cm between rows, 100 cm between pairs (46 200 plants/ha) and legumes were planted between the pairs of rows (132 000 plants/ha). The second maize crop was fertilized following standard recommendations (161 kg N, 36 kg P2O5, 75 kg K2O/ha). No fertilizer was applied to any legumes. The experiment used a randomized complete block design with 4 replications in plots measuring 6.5 m x 5.0 m.

We recorded rainfall at the site; the quantity and distribution were in line with the 10-year average. We calculated the land equivalent ratio (LER); examined crop growth, yield and yield components; both monitored soil loss and estimated it by the peg method; and calculated the land use efficiency and economic effectiveness of sole cropping and intercropping.
Analysis of variance was computed and means were separated using Fisher’s protected LSD test.

The LER was not significantly different between sole cropping and intercropping (Table 1).

**Table 1.** Land equivalent ratio (LER) of sole cropping and intercropping.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield alone (t/ha)</th>
<th>Yield in intercrops (t/ha)</th>
<th>LER maize</th>
<th>LER legume</th>
<th>LER maize legume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize + black bean</td>
<td>3.71</td>
<td>1.18</td>
<td>2.27</td>
<td>0.43</td>
<td>0.61</td>
</tr>
<tr>
<td>Maize + peanut</td>
<td>3.71</td>
<td>0.63</td>
<td>2.30</td>
<td>0.21</td>
<td>0.62</td>
</tr>
<tr>
<td>Maize + soybean</td>
<td>3.71</td>
<td>1.23</td>
<td>2.31</td>
<td>0.36</td>
<td>0.62</td>
</tr>
</tbody>
</table>

CV% 9.24

The second crops gave good yield gains, ranging from 0.63 t/ha from sole peanut to 3.71 t/ha from sole maize. Among the second crops, sole cropping gave higher yields than intercropping (Tables 2, 3). This result is consistent with other studies (Ranamukhaarachchi et al. 2005). We assume that it is explained by competition for resources when C3 and C4 plants are mixed (Rajat and Singh 1979; Midmore 1993).

**Table 2.** Maize yield components in sole cropping and intercropping in second crop season.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of cobs/ plant</th>
<th>Number of grains/ cob</th>
<th>1000 grain weight (g) at 14% moisture</th>
<th>Practical yield* (Mg grain/ha at 14% moisture)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize (sole crop)</td>
<td>1.20 ± 0.14</td>
<td>410.55 ± 59.12b</td>
<td>222.41 ± 5.68</td>
<td>3.71 ± 0.33</td>
</tr>
<tr>
<td>Maize + black bean</td>
<td>1.28 ± 0.17</td>
<td>461.98 ± 50.78a</td>
<td>216.64 ± 6.48</td>
<td>2.27 ± 0.42</td>
</tr>
<tr>
<td>Maize + peanut</td>
<td>1.28 ± 0.10</td>
<td>454.78 ± 55.34ab</td>
<td>218.42 ± 5.13</td>
<td>2.30 ± 0.27</td>
</tr>
<tr>
<td>Maize + soybean</td>
<td>1.38 ± 0.13</td>
<td>347.75 ± 26.19c</td>
<td>215.11 ± 3.26</td>
<td>2.31 ± 0.30</td>
</tr>
</tbody>
</table>

Different letters within a column show significant differences between sole crop and intercrop at P = 0.05.
*Quantity of grain harvested divided by the total surface area of main plots.

**Table 3.** Legume yield components in sole cropping and intercropping.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of pods/ plant</th>
<th>Number of seeds/ pod</th>
<th>1000 seed weight (g)</th>
<th>Yield (Mg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peanut (sole crop)</td>
<td>13.18 ± 0.99a</td>
<td>2.05 ± 0.13</td>
<td>509.67 ± 8.25a</td>
<td>0.63 ± 0.09</td>
</tr>
<tr>
<td>Peanut (intercrop)</td>
<td>11.03 ± 0.84b</td>
<td>1.80 ± 0.12</td>
<td>495.00 ± 6.88b</td>
<td>0.21 ± 0.03</td>
</tr>
<tr>
<td>Soybean (sole crop)</td>
<td>19.65 ± 1.60</td>
<td>2.25 ± 0.19</td>
<td>166.88 ± 1.19a</td>
<td>1.23 ± 0.17</td>
</tr>
<tr>
<td>Soybean (intercrop)</td>
<td>17.45 ± 1.02</td>
<td>2.25 ± 0.13</td>
<td>163.67 ± 1.04b</td>
<td>0.36 ± 0.06</td>
</tr>
<tr>
<td>Black bean (sole crop)</td>
<td>11.65 ± 0.45a</td>
<td>13.33 ± 0.82</td>
<td>130.68 ± 2.16</td>
<td>1.18 ± 0.13</td>
</tr>
<tr>
<td>Black bean (Intercrop)</td>
<td>10.55 ± 0.19b</td>
<td>12.98 ± 1.23</td>
<td>130.22 ± 1.23</td>
<td>0.43 ± 0.05</td>
</tr>
</tbody>
</table>

Different letters within a column show significant differences between sole crop and intercrop of a given legume at P = 0.05.
In all treatments, cultivation of a second crop with minimum tillage reduced the soil losses by erosion and runoff from 34 Mg/ha under fallow to 20–25 Mg/ha.

Although this experiment will need to be repeated to take into account interannual rainfall variability, our results reveal that double cropping has potential on sloping Acrisols at 800 m a.s.l. given average rainfall. By planting the first crop in March and harvesting it in June, farmers could grow a second crop during July to October. Further research using agroclimatic models is needed to determine the potential interannual risk and appropriate range of soil and elevation conditions.

Keywords
Intercropping, sole cropping, sloping lands, minimum tillage

References
Intercropping of upland rice with common bean under no-till (NT) culture offers a way to intensify sustainable agricultural production on ferralitic soils of sloping upland regions in Madagascar known as ‘tanety’. Conservation agriculture on such soils, which are characterised by low phosphorus (P) availability, presents great potential for rural development, especially by recycling nutrients such as P and nitrogen (N), and in contributing to carbon sequestration (Razafimbelo 2005).

We compared yields of intercropped upland rice–common bean under conventional tillage (CT) and NT with mineral inputs of P (as triple superphosphate: TSP) and organic inputs of P (as compost and residues of stylosanthes: *Stylosanthes guianensis* (Aubl.)) on ferralitic soil of the Malagasy highlands.

*Tanety* soils are characterised by a low availability of P due to high amounts of iron and aluminium oxyhydroxide. Much work has been done to increase the availability of P and hence crop yields. We showed that soil P availability and yields of upland rice (*Oryza sativa*) and bambara groundnut (*Vigna subterranea* (L.) Verdc.) under CT were increased with P inputs on ferralitic soils (Andriamananjara 2011; Henintsoa 2011). We wanted to know whether P inputs under NT gave comparable yields.

Two crops of upland rice (‘FOFIFA 154’) and common bean (*Phaseolus vulgaris* ‘Ranjomomy’) were intercropped in 2011–2012 in a field experiment at Lazaina (18°46′53.56″S, 47°32′05.03″E, 1290 m a.s.l.). The main objective was to identify the rate of P input, the type of organic matter input and the soil management system that improved crop yields.

We combined CT and NT with 2 rates of TSP, 5 and 20 kg P ha⁻¹, which correspond respectively to a very low and a moderate input of P (TSP5 and TSP20); and with either compost to supply 20 kg P ha⁻¹ (M20) or *Stylosanthes* residues to supply 20 kg P ha⁻¹ as green manure (GM20). The compost was made from rice straw and cow manure and had a P content of 0.2%. The *Stylosanthes* had a P content of 0.11%. The TSP had a P content of 19%. We tested treatment combinations of CT-TSP5-M20, NT-TSP5-M20, CT-TSP20-M20, NT-TSP20-M20, CT-TSP20-GM20 and NT-TSP20-GM20.
All treatments were replicated 4 times, and their distribution within each block was completely randomised. Each plot measured 24 m² (6 m x 4 m). K₂SO₄ was added to each treatment at 40 kg K ha⁻¹. No N fertiliser was added, so as to avoid the inhibition of symbiotic N fixation.

The experiment started in November 2011 on soil that has grown maize (*Zea mays* L.), bambara groundnut and upland rice since 2006. Beans were harvested in February 2012 and rice in April 2012. After harvest, the yield data were analysed by Student’s parametric t-test at α = 0.05.

The form of tillage (NT vs. CT) had no significant effects on rice yield. These results might be explained by the low mineralisation of nutrients from the manure or residues, especially under NT, probably because of the lack of rainfall (Nachimuthu et al. 2009). The rate of mineral P input had no effect on the yield of rice under NT with manure. However, compost gave a significantly higher rice yield than green manure (NT-TSP20-M20 vs. NT-TSP20-GM20).

Similarly, the form of tillage had no significant effects on bean yield. However, the yield in CT-TSP20-M20 (250 kg ha⁻¹) was significantly higher than that in NT-TSP20-M20 (122 kg ha⁻¹), showing the effectiveness of CT under moderate mineral P input. As above, the rate of mineral P input had no effect on the yield of bean under NT with manure. In addition, the organic form of P had no significant effect.

The results from the first year of the experiment show the same effects of NT and CT on yields on account of the slow nutrient cycling in tanety soil, which is controlled by water availability. The immediate effect of NT on crop productivity was not significant because of the slow decomposition of the *Stylosanthes*. Productivity should improve in the long term.

**Keywords**

Conventional tillage, zero-tillage, yield, organic matter

**References**


Deep tillage and mulching increase soil moisture storage and thus productivity of maize–wheat in the outer Himalaya foothills

Sanjay Arora*¹, Vikas Sharma¹ and V.K. Jalali¹

¹Division of Soil Science and Agricultural Chemistry, Faculty of Agriculture, S.K. University of Agricultural Sciences and Technology, Chatha, Jammu, Jammu and Kashmir 392012, India

* Corresponding author: aroraicar@gmail.com, Present address: CSSRI, RRS, Bharuch, Gujarat, India

Maize is grown extensively during the summer monsoon in rotation with wheat in the foothills of the Siwaliks (outer Himalayas) region, which covers about 12% of Jammu and Kashmir state, India. This region suffers seriously from soil erosion due to uneven topography, high soil erodibility, low soil fertility and high rain erosivity (Gupta et al. 2010). Rains are highly erratic and are often heavy. Summer monsoon rains, from July to September (Arora 2006), produce 20 to 30 rainstorms, of which 8 to 12 create runoff. Runoff ranges from 35% to 45% of rainfall, and soil loss is estimated to be about 36 t ha⁻¹ year⁻¹ (Hadda et al. 2008). The water table is deep to very deep, and rainfall is the only source of water in the region. The lack of irrigation facilities and high soil erosion put major limitations on the agricultural economy, resulting in poor socioeconomic status of the farmers (Arora et al. 2006). Thus, there is a need to enhance crop yields through in situ moisture conservation coupled with proper land and soil management practices in the region.

We conducted field experiments in a cluster of 5 villages in the Basantar catchment of Jammu region, in the foothills of the Siwaliks. We evaluated different tillage depths and modes of mulching in comparison with the farmers’ practice of mouldboard ploughing to a depth of merely 7–10 cm (Arora and Bhatt 2006). The treatments in maize comprised shallow tillage (10–15 cm), deep tillage (25–30 cm), partial spread-mulching, full spread-mulching, partial strip-mulching and full strip-mulching. The treatments were replicated thrice in a randomised complete block design in each village.

The average soil moisture was 30.3% greater under shallow tillage and 45.7% greater under deep tillage than under farmers’ practice. The grain yields were respectively 13.7% and 20.5% higher. Mulching increased soil moisture storage; maximum storage was achieved under full strip-mulching (Fig. 1). The grain yield under full strip-mulching was 32.7% higher than under farmers’ practice (Fig. 2) and 12.2% higher than with deep tillage. In the following wheat crop, the average grain yield was higher with shallow tillage than with deep tillage, and was 51.3% higher under full strip-mulching than in the unmulched control and 27.7% higher than with shallow tillage.
The real benefit of in situ moisture conservation is shown in wheat, which grows during the time of moisture deficit. The conserved moisture helps in germination and is the major factor increasing yield.

Figure 1. Mean moisture storage as a result of mulching. M1, farmer’s practice (no mulch); M2, partial spread-mulching; M3, full spread-mulching; M4, partial strip-mulching; M5, full strip-mulching.

Figure 2. Influence of mulching on yield of maize. M1, farmers’ practice (no mulch); M2, partial spread-mulching; M3, full spread-mulching; M4, partial strip-mulching; M5, full strip-mulching.
Keywords

Sloping lands, India, moisture conservation

References


Trials of tillage and fertiliser rate in winter wheat in the Aral Sea basin, Uzbekistan

A. Nurbekov*1, T. Friedrich2, H. Mauminjanov3, R. Ikramov4, Z. Ziyadullaev5

1 ICARDA-CAC, Tashkent, Uzbekistan
2 FAO, Rome, Italy
3 FAO/SEC, Ankara, Turkey
4 Central Asian Research Institute of Irrigation, Tashkent, Uzbekistan
5 Research Institute of Breeding and Seed Production of Cereals Crops, Karshi, Uzbekistan

*Corresponding author: a.nurbekov@cgiar.org

Recent findings from Uzbekistan have shown that during the transition to conservation tillage (CT), the need for N by irrigated crops did not differ between intensive tillage (IT) and CT practices (Devkota 2011). In farmers' fields in Chimbay district, Autonomous Republic of Karakalpakistan, Uzbekistan (42°57.091’ N, 59°45.798’ E, 69 m a.s.l.), we conducted two 4-year experiments. In 2004, winter wheat was planted at the beginning of November and harvested in mid June. In the following years, wheat was planted in mid October. The first experiment had 4 treatments: IT, minimum tillage with chiselling, minimum tillage with discing and no-till (NT). The objective was to see whether high wheat yields could be obtained under NT. The second experiment evaluated 5 treatments: IT with 120 kg N/ha and NT with 100, 120, 140 or 160 kg N/ha. N was managed for intensive production, with 1/3 applied at the tillering stage and the remainder at the jointing stage. Each experiment used a randomised complete block design with 4 replications. The plot size was 200 m² (25 m x 8 m). Data were analysed with GenStat software.

After 4 years, the organic carbon content in the top 10 cm of the soil was highest under NT (Table 1). This is explained by the absence of tillage. Yields of both rice and wheat in rice–wheat culture showed a positive response to increased levels of organic matter (Mohanty et al. 2007). There are three main kinds of organic matter in soil: the visible root system, the partly decomposed remains of plants and the well decomposed organic matter, commonly called humus (Mirzajanov 1971). Humus is less able to produce decomposition products that help to stabilise the soil than is fresh or partially decomposed organic matter (Stoskopf 1981). In our experiments the humus content increased remarkably, but there were no significant differences in soil P or K between the two tillage systems. The effect of crop residues on soil fertility should be further tested. Taking into account the slow decomposition of organic manure and crop residue it is too early to draw general conclusions, but our results are encouraging.
The rate of N had no significant effect on yield (Table 2). NT + 140 kg N/ha produced a yield increase that was statistically significant across the 4 years. The highest yield (3051 kg ha\(^{-1}\)) was recorded in NT + 140 kg N/ha in 2008, and the lowest (1733 kg ha\(^{-1}\)) in NT + 100 kg N/ha in 2005 (Table 2).

### Table 1. Soil chemical parameters in the different tillage systems (2005–2008).

<table>
<thead>
<tr>
<th>Soil characteristics</th>
<th>2005</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CT</td>
<td>MTC</td>
</tr>
<tr>
<td>Organic carbon (%)</td>
<td>0.612</td>
<td>0.612</td>
</tr>
<tr>
<td>Nitrogen (%)</td>
<td>0.045</td>
<td>0.045</td>
</tr>
<tr>
<td>Phosphorus (%)</td>
<td>0.141</td>
<td>0.141</td>
</tr>
<tr>
<td>N as NO(_3), mg/kg</td>
<td>12.87</td>
<td>12.87</td>
</tr>
<tr>
<td>P as P(_2)O(_5), mg/kg</td>
<td>27.84</td>
<td>27.84</td>
</tr>
<tr>
<td>K as K(_2)O, mg/kg</td>
<td>291</td>
<td>291</td>
</tr>
</tbody>
</table>

CT, conservation tillage; MTC, minimum tillage with chiselling; MTD, minimum tillage with discing; NT, no-till.

### Table 2. Winter wheat yields under different tillage methods and N rates (2005–2008).

<table>
<thead>
<tr>
<th>Tillage methods and N rates</th>
<th>Mean grain yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005</td>
</tr>
<tr>
<td>IT with N 120 kg/ha</td>
<td>1823</td>
</tr>
<tr>
<td>NT with N 100 kg/ha</td>
<td>1733</td>
</tr>
<tr>
<td>NT with N 120 kg/ha</td>
<td>2234</td>
</tr>
<tr>
<td>NT with N 140 kg/ha</td>
<td>2331</td>
</tr>
<tr>
<td>NT with N 160 kg/ha</td>
<td>2129</td>
</tr>
</tbody>
</table>

Tillage n.s.
Year <0.001
Year x tillage <0.001

**Keywords**

Winter wheat, no till, humus content, nitrogen rate, yield

**References**


Portfolio 5. Agricultural efficiency of CA systems

The goal is to permanently produce large amounts of biomass to cover the soil, which not only protects soils from erosion, but also helps to optimize water management by limiting losses due to evaporation and runoff, while enhancing infiltration which tops up the soil water reserve (305).

305a – Laos
Differential impact of cropping systems on erosion and runoff. DMC (left) / ploughing (right)

305b - Cameroon
Differential impact of cropping systems on resistance to climate risks. Ploughing (left) vs. DMC (right)

305c – Cameroon
Impact of cropping systems on early sowing possibility. DMC (left) vs. ploughing (right)

305f – Cameroon
Soil differentiation process under DMC (bottom) compared with minimum tillage (middle) and ploughing (top)
Soil cover also enables better weed control (306).

306b – Laos
Long cycle rice bean in rotation with rice or maize enables efficient weed control

306c - Laos
Thick rice bean mulch ensuring a weed control

306a - Laos
Rice on a mulch of *Stylosanthes guianensis* ensuring weed control
Above-ground plant biomass limits soil and water pollution by chemicals (the litter acts as a physical and chemical filter), whilst restoring the biological activity of soils. It is the driving force of DMC (307).

307a – Laos
The abundance of earthworms in a soil under DMC is an indicator of macrofauna biological activity

307b – Guadeloupe (France)
Thickness of a mulch of Brachiaria ruzi in a DMC system. As it decays, the mulch increases soil organic matter.

307c – Madagascar
The quantity, quality and frequency of organic matter inputs are key factors of DMC efficiency.

307d – Brazil
Density of mycelium in a soil cultivated under DMC is an indicator of intense biological activity.

307e – Laos
Earthworm faeces in a rice-based cropping system on Brachiaria ruzi and pigeon pea covers.
The efficiency of DMC systems more particularly depends on the multi-functional plants used in association or in rotation with the targeted commercial crops. These cover plants are selected for their abilities to produce large amounts of organic matter, both above and below ground, restore soil fertility and optimize marginal climatic seasons for commercial crops (308).

308a - Laos
Cover of finger millet (*Eleusine coracana*), a plant able to restore fertility of degraded soils

308b - Cameroon
Association of rattlerpod and finger millet to restore an indurated and degraded gravelly soil in the Sudan-Sahel zone

308c - Laos
Finger millet and pigeon pea used to improve soils before growing cash crops

308d - Laos
Finger millet cultivated to improve soils before sowing cash crops

308e - Laos
Finger millet and pigeon pea grown to restore soil fertility

308f - Brazil
Field with a cover of *Stylosanthes guianensis*
Chapter 5

Social and Economic Implications of Conservation Agriculture

Vietnam
A shop selling hybrid maize seeds

D. Hauswirth, Son La, 02/2012
Conservation agriculture as an alternative to plough-based cassava cropping in the upland borders of Kampong Cham, Cambodia: preliminary results of extension

S. Chabierski*1, K. Rada2, S. Sona2 and S. Boulakia1
1 CIRAD-PERSYST, URSIA, Ministry of Agriculture, Forestry and Fisheries/GDA, Phnom Penh, Cambodia
2 PADAC, Ministry of Agriculture, Forestry and Fisheries/GDA, Phnom Penh, Cambodia

*Corresponding author: stephane.chabierski@cirad.fr

Conservation agriculture practices and direct-sowing mulch-based cropping (DMC) systems were introduced into Kampong Cham province, Cambodia, in 2004. This region is prosperous on account of its good soils and its large rubber plantations. Nevertheless, this view masks less favourable situations, in particular in the upland borders, which represent >50% of the upland arable area. Here, the farmers are mainly smallholders who have come to rely on cassava monocropping following declines in the productivity of maize and soybean and strong market solicitation. But continued upland degradation and wide variations in the price of cassava threaten agronomic sustainability and economic performance. In consequence, more and more farmers become trapped in poverty and must give up agriculture.

Within this context, PADAC was launched in 2008 by the Ministry of Agriculture, Forestry and Fisheries of Cambodia, with the technical support of CIRAD and the financial support of the AFD, to develop, test and promote DMC technologies as a way to sustainably intensify annual crop production on uplands. PADAC promotes the biannual rotation of cassava and maize under *Stylosanthes guianensis* cover.

Our objectives were i/ to compare the technical and economic performance of DMC-based cropping systems adopted by farmers at the plot scale with conventional plough-based monocropping of cassava; and ii/ to highlight a strategic approach that promotes the adoption of such techniques in Kampong Cham.

A plot network incorporating central plots for the design and evaluation of cropping systems, collections of planting material (for introduction, evaluation and initial multiplication), demonstration plots and a network of farmers was established to gather feedback on the innovations introduced and data on their adaptation, and to evaluate the replicability of DMC under farm conditions. The farmers were trained in mastering DMC techniques on their land and in contributing to the organisation of the village community through access to mechanisation, the development of services around DMC adoption, connection with suppliers, the production of cover crop seeds and marketing of produce. During 2011-12, 297 farmers adopted DMC technologies on a total area of 234 ha in 9 villages. We chose 5 villages, considered ‘pioneer villages’, for our study (296 plots under DMC on 172 ha in 2011).
We compared the economic performance of the farmers’ plots within the project with that of 35 plots managed traditionally, during 2009–10, 2010–11 and 2011–12. Yields were recorded in the field. The gross profit margin was computed by deducting all operational costs (inputs, external labour etc.) from the value of production. Technicians assessed the farmers’ knowledge of DMC technologies daily in the field. In addition, a number of focus group discussions were held to get feedback from the farmers about the capacity management of the farmers’ organisation leaders in coordinating service provision and about further requirements for DMC adoption.

Yields increased with time with DMC practices (Table 1). Cassava production increased from 7.6 Mg/ha in 2009 to 11.1 Mg/ha in 2011, but decreased from 6.4 Mg/ha to 5.5 Mg/ha with traditional management. The global enhancement of performance regardless of the time since DMC adoption attested to the fact that the farmers improved their overall crop management (e.g. application of fertilisers, control of density, improved weed control thanks to proper use of herbicides). In contrast, the high standard deviations show that the technical level is still heterogeneous and the biophysical conditions are variable.

Table 1. Yield by cropping system and time since adoption of DMC practices, 2009–2012.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yield (±SD) (Mg/ha)</td>
<td>Plots (Nº)</td>
<td>Yield (±SD) (Mg/ha)</td>
</tr>
<tr>
<td>Cassava + Stylosanthes guianensis (1 year)</td>
<td>7.6 (± 2.9)*</td>
<td>83</td>
<td>8.05 (± 2.7)</td>
</tr>
<tr>
<td>Cassava + Stylosanthes guianensis (2 years)</td>
<td>9.1 (± 1.7)</td>
<td>9</td>
<td>9.3 (± 2.8)</td>
</tr>
<tr>
<td>Cassava + Stylosanthes guianensis (3 years)</td>
<td>11.1 (± 3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control: cassava, conventional management</td>
<td>6.4 (± 3.1)*</td>
<td>32</td>
<td>5.9 (± 2.4)</td>
</tr>
<tr>
<td>Maize + Stylosanthes guianensis (1 year)</td>
<td>3.8 (± 0.5)</td>
<td>6</td>
<td>3.1 (± 1.1)</td>
</tr>
<tr>
<td>Maize + Stylosanthes guianensis (2 years)</td>
<td>3.5 (± 0.8)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Yield of peeled, sun-dried cassava (~45% of fresh weight).

DMC-based cassava cropping returned gross profit margins of ~930 USD/ha after 3 years, whereas conventional management returned only ~410 USD/ha (Fig. 1). DMC-based maize cropping (grown in rotation with cassava) returned 400 USD/ha in year 2. However, we could not compare this system with conventional plough-based maize cropping, which is not grown any more in the study area. As the DMC-based cassava proved more profitable than maize, this limits the adoption of the recommended rotation.
Farmers’ decisions on technology adoption are often conditioned by attractive short-term economic considerations. These results do not separate the ‘pure agronomic effect’ and the ‘learning effect’. Some complementary statistical trials implemented in 2012 should help to answer to this question.

**Figure 1.** Gross profit margin (USD/ha) by cropping system and time since adoption of DMC practices (Kampong Cham province, farmers network, 2009–2012).

Market prices: cassava, 150 USD/t of dry tubers; maize, 250 USD/t of dry grain.

After 3 cropping campaigns, the farmers became progressively more autonomous in the purchase of chemical inputs (fertilisers, herbicides), increased their knowledge of conservation agriculture and were able to provide services within their community (herbicide treatments, maize threshing...). However, efforts made to enhance the production of cover crop seeds and to establish sustainable partnerships with the private sector (contract agriculture) have so far been insufficient. In addition, >40% of the farmers returned to traditional management every cropping season, considering these technologies as too risky (with a level of investment higher than in traditional management). Analysis of the drop-out rates on different farm types will help us to analyse the adoption processes. Such information is required before further extension and extrapolation.

**Keywords**

Smallholders, DMC technologies, technology adoption
Potential of conservation agriculture as an alternative to maize monocropping in mountainous areas of Vietnam

Damien Hauswirth*1, Hoang Xuan Thao2, Nguyen Quang Tin2, Dam Quang Minh2, Nguyen Van Sinh2, Le Viet Dung2, Nguyen Phi Hung2 and Ha Dinh Tuan†2

1 CIRAD, UPR SIA, F-34398 Montpellier, France
2 NOMAFSI, Phu Ho Commune, Phu Tho District, Phu Tho Province, Vietnam

*Corresponding author: damienhh@gmail.com

Maize is the main annual crop on the slopes of the northern mountains of Vietnam. Its cultivation usually involves tillage of bare soils and spraying of herbicides at the beginning of the rainy season. These practices raise concerns over pollution and soil erosion (Valentin et al. 2008). Conservation agriculture (CA) would allow farmers to intensify agricultural production sustainably in those areas.

Within the scope of the AFD-funded ADAM project (Support for Agroecology Extension in Mountainous Areas of Vietnam), our study compared the technical and economic feasibility of a range of alternative, no-till (NT) cropping systems characterised by permanent soil cover, no tillage of crop residues, and a range of associate relay-cropping species, including Crotalaria sp., Stylosanthes guianensis, Brachiaria ruziziensis, Mucuna pruriens, rice bean (Vigna umbellata) and oats (Avena sativa) with conventional tilled (CT) maize monocropping systems.

These options were tested at 4 reference sites: Suối Giàng (Van Chan, Yen Bai), Phiên Luông and Чиềng Hắc (Moc Chau, Son La) and Чиềng Ban (Mai Son, Son La). Three fertiliser levels were tested: F0 (N-P-K = 23-0-0), F1 (69-35-30) and F2 (115-85-60 + micronutrients applied once for 3 years). Experimental sites differed in biophysical conditions, including soil type, elevation (505–980 m a.s.l.), number of crops grown and potential to mechanise (slope of 8°- 40°). At each site, treatments were repeated 3 times.

At harvest, maize production was recorded in the field (3 samples of 8 m² per replicate plot), and subsamples were taken to determine the cob-to-grain ratio and moisture percentage. N fertiliser efficiency and N agronomic efficiency (Ladha et al. 2005) were estimated for each system. Maize biomass was recorded at harvest from 10 plants per plot. The quantity of biomass before sowing was assessed by eye and by weight per 0.5-m x 0.5-m quadrat in the field.

Analysis of variance was used to identify the main factors explaining yield variations. Tukey’s and Bonferroni’s tests were used to separate groups of treatments with statistically significant differences (P = 0.05) in average yields.
Labour requirements and input costs for each activity were recorded annually on site and compared with those assessed from a farmer survey at the district level. Return on land and labour were assessed for each system.

Return on land initially excluded labour costs (considering any agricultural activity as performed exclusively by family members). Since few farmers hired temporary labour for most maize cultivation activities, return on land including labour costs was also determined (thus considering all agricultural activities as implemented by daily waged labourers). Economic calculations considered maize prices at harvest. Only cover plants whose grain had commercial value were integrated in the calculations. A mean conversion rate of 1 USD = 20 000 VND was used in all calculations.

Yield gain

In the first year of the trial, NT on crop residues (<1 t/ha sun-dried biomass at sowing covering ≥30% of soil) did not increase maize yields at most sites (data not shown). Hence, maize yields for a given level of fertiliser under CT and NT were not significantly different (P > 0.05) at Suoi Giang (2010), Phieng Luong (2010) and Mai Son (2011). At Chieng Hac only (2011), NT on crop residues gave a significant 13% increase in maize yield over CT. We assumed that the improvement was linked to the uptake of more fertiliser N due to modification of sowing or weeding practices under NT. In the second year, NT on crop residues significantly increased maize yields in Suoi Giang (F1 and F2 in crop 1, F2 in crop 2), Chieng Hac (F2) and Phieng Luong (F0) (Table 1).

Table 1. Maize grain yields (kg/ha at 14% moisture) recorded in the second year of the trial.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Crop 1</td>
<td>Crop 2</td>
<td>Crop 1</td>
</tr>
<tr>
<td>F0 (23–0–0)</td>
<td>Tillage</td>
<td>3.208 a</td>
<td>1.839 a</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>NT</td>
<td>3.571 a</td>
<td>2.066 a</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>NT</td>
<td>4.975 B</td>
<td>3.617 A</td>
<td>2.982 A</td>
</tr>
<tr>
<td>F2 (115–85–60)</td>
<td>Tillage</td>
<td>5.684 α</td>
<td>3.863 α</td>
<td>2.254 α</td>
</tr>
<tr>
<td></td>
<td>NT</td>
<td>6.126 β</td>
<td>4.309 β</td>
<td>4.003 β</td>
</tr>
</tbody>
</table>

1 There were significant interactions between level of fertiliser and cultivation method, so analyses were performed for each level of fertilisation separately. Values within a crop followed by the same letter are not significantly different (P > 0.05).

Land productivity at field scale

We identified NT systems that increased return on land in the short term at all sites, although for different reasons. At Suoi Giang (2 crops per year), NT monocropping of maize with Mucuna as a relay crop in the second season gave an additional 158–240 USD/ha per year compared with CT (Table 2). This result was due mainly to the positive effect of the crop residues, since the Mucuna was unable to complete its cycle and produce pods.
At Phieng Luong, maize associated with *crotalaria* (with no commercial value) at sowing gave an additional 50 USD/ha per year under F1 and 250 USD/ha under F2 for similar reasons. At Chieng Hac, maize monocropping (1 crop per year) with oats as a winter crop partially grazed gave an additional 85 USD/ha. The improvement would be higher if farmers could protect the oats from free grazing during winter. NT maize monocropping with *Mucuna* (1984 kg seeds/ha) as a relay cover plant gave the best economic result, providing that the *Mucuna* can be sold (Table 3).

**Table 2.** Economic returns in Suoi Giang (manual agriculture, 2 cropping seasons per year, 2011).

<table>
<thead>
<tr>
<th></th>
<th>Conventional maize monocropping (2 crops / year)</th>
<th>No-till maize (2 crops) with Mucuna as a relay crop</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F0</td>
<td>F1</td>
</tr>
<tr>
<td>Total income (2 crops, USD/ha)</td>
<td>1648</td>
<td>2465</td>
</tr>
<tr>
<td>Input cost (USD/ha)</td>
<td>161</td>
<td>426</td>
</tr>
<tr>
<td>Labour requirements (2 crops, working days/ha)</td>
<td>455</td>
<td>469</td>
</tr>
<tr>
<td>Return on labour (USD/working day)</td>
<td>3.3</td>
<td>4.3</td>
</tr>
<tr>
<td>Return on land excluding all labour costs (USD/ha)</td>
<td>1645</td>
<td>2461</td>
</tr>
<tr>
<td>Return on land including all labour costs (USD/ha)</td>
<td>−173</td>
<td>585</td>
</tr>
</tbody>
</table>

**Table 3.** Economic returns in Chieng Hac (animal traction, 1 cropping season, 2011).

<table>
<thead>
<tr>
<th></th>
<th>Animal-tilled maize monocropping (1 crop/year)</th>
<th>No-till maize with Mucuna as a relay crop</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F1</td>
<td>F2</td>
</tr>
<tr>
<td>Income from maize and <em>Mucuna</em> (USD)</td>
<td>1304</td>
<td>1449</td>
</tr>
<tr>
<td>Input cost (USD)</td>
<td>304</td>
<td>640</td>
</tr>
<tr>
<td>Labour requirements (working days), crop 1</td>
<td>179</td>
<td>179</td>
</tr>
<tr>
<td>Return on labour (USD/working day)</td>
<td>5.6</td>
<td>4.5</td>
</tr>
<tr>
<td>Return on land excluding all labour costs (USD/ha)</td>
<td>1001</td>
<td>808</td>
</tr>
<tr>
<td>Return on land including all labour costs (USD/ha)</td>
<td>287</td>
<td>94</td>
</tr>
</tbody>
</table>

**Labour requirements**

Under manual production, labour requirements were equivalent during the first year under CT and NT, as savings on ploughing were offset by spraying of herbicide for mulch preparation and sowing of relay cover plants under NT. During the second year at Suoi Giang, labour requirements under NT were 14% to 27% lower than under CT in the first cropping season and up to 18% lower in the second. At Phieng Luong, labour requirements were equivalent for NT that allowed similar use of herbicides as CT, and up to 37% higher for NT managed with manual weeding.

In the context of mechanised ploughing and during the first year of the trial, labour requirements in NT were 34% to 100% higher than in CT at Mai Son and at Chieng Hac, mainly owing to the manual management of the associated crops, in addition to lack of specific equipment for NT implementation with animal traction (roller and direct seeder) at the time.
Although our results demonstrate the potential of NT to increase maize yields in northern Vietnam, they confirm that only slight changes in the management of NT options (broadcasting seeds versus sowing by hole; chemical weed management versus manual weed management) have great impact on labour requirements and thus on the potential interest of farmers in such alternatives. Adapting developed technologies to the local economic context and to the diversity of constraints at the farm level thus remains of primary importance (Affholder et al. 2010).

Our findings also have practical implications for scaling up of alternative CA options:

- Under contexts of mechanised production, lack of availability of commercial direct seeders in Vietnam is a critical limitation. Direct seeders for animal and motorised traction should be introduced, together with the broadcasting of associated relay crops.
- For farmers whose labour productivity is of higher importance than land productivity, NT on maize residues without relay cropping may be recommended as non-optimal option during the conversion to CA.
- For farmers constrained mainly by access to land, NT systems with relay cropping (Mucuna, rice bean) or winter succession (oats) can be recommended. We assumed that such options will be of economic interest only if cover plants can be sold or used on farm.
- NT systems with Mucuna have potential for the highest economic return, because Mucuna can be fed to cattle or pigs or can be sold to the pharmaceutical industry, since Mucuna extracts are of interest in the treatment of Parkinson’s disease (Katzenschlager et al. 2004).

**Keywords**

No-till, Vietnam, maize, technical efficiency, feasibility

**References**


On-farm performance evaluation of conservation agriculture production systems in the central middle hills of Nepal

Bikash Paudel¹, Theodore Radovich², Susan Crow¹, Jacqueline Halbrendt¹, Catherine Chan-Halbrendt¹, B. B. Tamang³, Brinton Reed¹ and Keshab Thapa³

¹ Department of Natural Resources and Environmental Management, University of Hawaii at Manoa, 1910 East West Rd, Sherman 101, Honolulu, Hawaii 96822, USA
² Department of Tropical Plant & Soil Sciences, University of Hawaii at Manoa, St John Plant Science Lab 102, 3190 Maile Way, Honolulu, Hawaii 96822, USA
³ Local Initiatives for Biodiversity Research and Development, Pokhara 4, Gairapatan, PO Box 324, Kaski, Nepal

Corresponding author: paudel@hawaii.edu

Traditional agriculture in the central middle hills of Nepal is characterised by the cultivation of steeply sloping lands, resulting in the degradation of soil health and lower productivity. The Sustainable Management of Agroecological Resources in Tribal Societies project used a participatory agroecological research framework to develop an improved conservation agriculture (CA) production system (CAPS) to contribute to the sustainable livelihoods of marginalised tribal farmers.

Experimental plots were established in 24 farmers’ fields in 3 villages in the central middle hills of Nepal: Hyakrang village in the Jogimara village development committee (VDC) of Dhading district, Thumka village in the Bhumlichok VDC of Gorkha district, and Kholagaun village in the Chimkeshori VDC of Tanahun district (27°47–50’N, 84°30–41’E). The villages lie between 200 and 1000 m a.s.l., in a subtropical climate in which temperature decreases with increasing altitude. These villages were selected because they comprise predominantly members of the Chepang tribe, one of the most marginalised communities in Nepal. The available agricultural lands in this region are marginal, characterised by low natural productivity and sloping terrain. Historically, they have been used for shifting cultivation. However, increased population pressure has led farmers to rely on intensified agriculture, including reduced fallow periods (Kafle 2011), which has led to soil degradation and reduced yields. CA has been evaluated as a potential solution because it promotes a healthy agronomic environment and enhances economically sustainable production (Kassam et al. 2009; Jat et al. 2011).

Potential new CAPS technologies were identified through interactive village workshops of researchers, farmers and development workers. As a result, some principles of CA (viz. cropping system management, minimum tillage and soil cover management) were adopted to improve maize-based upland farming.
The first season’s (March–July) crop was maize, which was sown under either conventional tillage (CT) or strip tillage (ST). The CAPS treatments used in the second season (July–October) were cowpea under CT, millet–cowpea intercropping under CT, and millet–cowpea intercropping under ST. Millet–cowpea intercropping and ST are completely new technologies in the study area.

A randomised block experimental design with villages as blocks and farmers as replications was used. The experimental plots were completely managed by farmers using their own practices with very little external input. Agriculture technicians ensured proper implementation of CAPS on the farms and collected data on agronomy, yields and economics.

Crop yields and total biomass production were compared among the treatments using general linear regression models. Biomass production in intercropping was compared by estimating the land equivalency ratio (LER) (Osman et al. 2011). Crop yields were also converted to protein equivalent, carbohydrate equivalent and imputed revenue, and compared.

The maize and millet crops yielded only 1.14 ± 0.12 and 0.91 ± 0.28 Mg ha⁻¹, respectively, substantially less than the national averages (2.28 and 1.12, Mg ha⁻¹ respectively; MoAC 2011). Cowpea yielded 0.87 ± 0.19 Mg ha⁻¹, comparable to the national average (0.95 Mg ha⁻¹).

The effect of village on maize yields in the first cropping season and on cowpea and millet yields in the second season was significant (P < 0.05). The effect of intercropping on millet yield was significant (P < 0.001), indicating a much lower yield in intercropping than in single cropping. Nevertheless, yields of maize and cowpea in intercropping were comparable to that of single cropping. Thus, although the yield of millet decreased, the farmers were compensated by cowpea yield. Yields of crops were comparable between CT and ST. Millet–cowpea intercropping under CT had significantly higher LER (1.20) than any single crops. This major gain was attributable to cowpea, which produced 75% of its single cropping yield in intercropping. However, the LER of millet–cowpea intercropping under ST was comparable to that with single cropping. Thus, ST reduced the overall biomass production during the first growing season.

Since most crop production is grown for household consumption, we also analysed how CAPS treatments affected the total protein and carbohydrate availability and revenue in households. We compared the protein and carbohydrate yields of CAPS treatments (cowpea under CT, millet + cowpea under CT, millet + cowpea under ST) with traditional practice (millet under CT). The CAPS treatments significantly increased protein yield (P = 0.006) and revenue (P = 0.01) per hectare, but had no effect on carbohydrate yield. This analysis suggests that integrating cowpea in either single cropping or intercropping can increase protein availability and household revenue. This increased availability of protein is crucial, since protein deficiency is a major health problem in Nepal.
We assessed the preferences of 41 randomly selected farmers in regard to CAPS by using an analytic hierarchy process. The farmers were asked to list the factors that affect their agricultural income and weight them according to importance. The farmers perceived soil quality as the most important factor to their goal of improved income (49%), followed by yield (25%), profit (14%) and labour savings (11%). This perception is understandable, because quality of land directly affects income through yield, profitability and labour. Farmers ranked cowpea under CT as having the highest contribution to improved income (35%), followed by millet–cowpea intercropping under ST (34%) and millet–cowpea intercropping under CT (22%).

In conclusion, while the long-term effects of CAPS on soil and environmental health remain to be analysed, the initial results show positive impacts of cowpea intercropping with millet. Although ST seemed to reduce total biomass yield, the initial yields were still comparable. By increasing yields, CAPS can contribute to sustainable food and nutritional security in Nepal.

**Keywords**

Intercropping, strip tillage

**References**

Conservation agriculture adoption in Lake Alaotra, Madagascar

Eric Penot¹, Raphael Domas², Andriatsitohaina Rakotoarimanana³ and Eric Scopel¹

¹ DR CIRAD, BP 853, Anpandrianomby, 101, Antananarivo, Madagascar
² BRL Madagascar, Ambatondrazaka, Madagascar
³ Projet BV-lac, Ambatondrazaka, Madagascar, Tel: 00 261 33 14 699 51

Corresponding authors: penot@cirad.fr, scopel@cirad.fr, tsito@cirad.mg

Conservation agriculture (CA) was introduced in the Lake Alaotra region of Madagascar in the 2000s in the context of traditional but rapidly developing ‘mining’ upland agriculture and silting up of lowland irrigated rice fields. Land tenure pressure linked to the attractiveness of the area has led to the progressive colonisation of surrounding upland hills (tanety), which are very prone to erosion. CA in this region faces challenges: to maintain or increase agricultural production and household income for a population that doubles every 18 years, and to preserve natural resources in the long term. Five main CA systems have been promoted and partially adopted according to the associated plant species (Stylosanthes guianensis, Brachiaria, Dolichos, vetch and other legumes). Cropping systems have been suggested according to soil and plot situation (Domas et al. 2009): on low-fertility tanety with low-input cropping systems based on Dolichos and Stylosanthes; on relatively fertile tanety with potential for intensification; and on lowlands with vetch-based systems.

This paper describes the introduction and adoption of CA and presents an assessment of the economic impact on farmers’ income through modelling of representative farms selected according to a local typology. CA adoption in Lake Alaotra through the ‘BV-lac’ development project, funded by l’Agence Française de Développement, can be considered a relative success. CA has increased yields moderately, buffered the effects of climate hazards through mulching and stabilised agricultural production, leading to its adoption as part of a global risk-limiting strategy. Most CA systems are nowadays low-input cropping systems, as fertiliser prices have doubled since 2008, and have now stopped the trend of ecological intensification widely adopted in 2003. Therefore, CA has delivered its benefits without any commercial fertilisers. There is still a large reservoir of productivity if fertiliser prices drop again.

CA systems increase farming systems’ resilience to climatic events and price volatility, as well as maintain local and fragile resources. However, its adoption is not easy. The main constraints are a long learning process (3–5 years), the need for good technical information, the need to wait several years to see the agronomic advantages and, perhaps most importantly, the apparent absence of spontaneous diffusion of CA systems sensu stricto outside the project area.
This last point appears to be a major constraint to the further adoption by surrounding communities in the near future (as the project ends in May 2013). CA adoption in the long term is clearly not easy, and the long learning process is in itself a major constraint to further adoption.

Some elements of CA techniques have been adopted spontaneously by surrounding farmers, leading to the improvement of intensive-tillage-based systems, but CA as a whole is rarely adopted without proper mid-term extension. In essence, practices linked with 1 or 2 of the 3 main CA themes (no tillage, associated plant and mulch, crop rotation) might be adopted in what we call ‘innovative cropping systems’, but not the whole CA package.

Modelling with the Olympe budget analysis tool has highlighted that CA systems significantly improve net farm income in the mid term (5–10 years) and gross margins at the plot scale in the short term.

This abstract presents the main results of CA adoption after 8 years of extension and 6 years of associated research. The methods included modelling a Farming System References Monitoring Network (FSRMN) during 4 years, farming systems surveys and in-depth studies of specific topics such as livestock integration, farm accounts and credit.

The BV-lac project worked with 3000 smallholders. Surveys of 300 farms led to the identification of 7 farm types and the identification of an FSRMN with 48 farms. Farming systems modelling and simulation prospective analysis, both retrospectively for CA adoption impact and prospectively for CA potential impact, were used to improve the current development of farm-level technical and farming counselling. Using a livelihood approach we measured impacts on cropping systems and global farming systems with Olympe. All research results were used to implement a decision support system at the project level with associated extension partners to better identify the pros and cons of CA for farmers. We assessed innovations and farm trajectories in order to measure resilience and evolution.

We monitored farming systems strategies to understand the main trends of future adoption. Smallholders display a high capacity for innovation, leading to a large continuum of improved practices and cropping systems from intensive tillage through partial adoption to CA. But 8 years of relatively good-quality extension might not prove enough to build a sufficient base of long-term CA adoption by smallholders. We still do not know whether the current adoption level is sustainable in the long run. In other words, does CA adoption lead to a real change of paradigm, a change in practices as well as the move from the traditional short-term strategy to a new mid- or long-term strategy (including 3 to 5 years’ crop rotation, for instance)? It seems too early to confidently predict a real long-term CA adoption and a global move to agricultural sustainability.

Ecological intensification remains to be done, depending on local economic constraints and fertiliser prices.
Future research and action will depend greatly on political evolution in the country, which has been in crisis since 2009, with no vision in terms of agricultural policy; the ability of the government to locally implement adapted policy, taking into account the need to boost production on upland agriculture; and the trust of farmers and traders in local commodity systems and the evolution of the economic situation, which poses risks that currently prevent any production boost.

**Keywords**

Innovation process, farming system modelling, impact and resilience

**Bibliography**


Parametric versus nonparametric approaches to assessing the performance of zero-till wheat in rice–wheat culture on the Indo-Gangetic Plains

Shyam Kumar Basnet

1Department of Economics, Swedish University of Agricultural Sciences, PO Box 7013, SE-750 07, Uppsala, Sweden

*Corresponding author: shyam.kumar.basnet@slu.se

This study was designed to analyse the impact of zero-till (ZT) technology on wheat production in rice–wheat culture on the Indo-Gangetic Plains. Because of limited turnaround time between the harvest of the rice crop and wheat sowing, ZT technology was introduced to improve yields and save costs. ZT technology has a yield advantage over intensive tillage (IT) and has lower costs for tillage operations and herbicide use. In a study in India, even though ZT wheat was plagued by weeds, Vincent and Quirke (2002) argued that the expenditure on herbicide use remained almost constant over the first few years of ZT use and then started declining over time as the size of the weed seed bank reduced. Lahmar (2010) observed some problems associated with this technology in European agriculture, such as higher incidence of weeds, pests and diseases, soil compaction and lack of technical knowhow in farmers.

Most studies have been based on average differences in variables measured on farm, but a number of socioeconomic and biophysical characteristics affect adoption by farmers. No previous studies have separated out their impacts from the treatment effect. Erenstein (2009) meticulously compared technology options among adopters, but his estimates were not free of imperfect control and plot selection biases. Here, I contrasted adopters and non-adopters, placing partial adopters in the adopters’ group, and collected information on a particular plot where ZT was practised. This contrast avoids individuals who possess both ZT and IT plots, and avoids the imperfect control and plot selection biases. To avoid the problems of self-selection bias raised by Erenstein (2009), I used a propensity score matching technique, which constructs a statistical counterfactual group based on the propensity scores estimated from observable covariates, and a set of matching criteria such as nearest-neighbour, kernel matching and genetic matching to provide the causal inferences. The technique is often used in other areas of economics, but parameters are defined to estimate the propensity scores.

1 ZT consists of a single pass of a tractor-drawn ZT seed-drill machine.
2 The Indo-Gangetic Plains cover large areas of Pakistan, India, Nepal and Bangladesh.
3 IT requires multiple passes of a tractor to accomplish land preparation.
Sekhon (2011) pointed out that the matching results are greatly affected by the specification of the propensity score model, and demonstrated the use of genetic matching algorithms with and without model specification. An algorithm without model specification does not provide consistent results, as it is stochastic and would have the same problem of appropriate model specification if we wished to have consistent estimates. To circumvent the problem of model specification, I used a nonparametric approach, as suggested by Bontemps et al. (2009).

An area-frame sample of points was selected randomly for a household survey in the Karnal and Bhairahawa clusters on the Indo-Gangetic Plains. In total, 8 projects and 4 control villages came from Karnal and 4 and 2 came from Bhairahawa. The project villages were selected randomly from the list of project villages, and the control villages were chosen to match their characteristics. Within each village, 20 farm households were selected randomly, and in total 353 farmers were interviewed on household characteristics, farm biophysical attributes, financial or management skills and other exogenous factors.

Both parametric and nonparametric specifications were used to estimate propensity scores, and a set of outcome variables (e.g. costs of tillage operation and herbicide use, crop yield, revenue and profit) were used to visualise the impacts. The nonparametric specification outperformed the parametric model, reflecting the relevance of land size, market access and literacy status in econometric estimations. Moreover, it gave greater significance to the harvest date of the previous crop, which is supposed to be a significant factor in inducing farmers to take up ZT. As expected, the nonparametric model showed the existence of heterogeneous treatment effects across locations, but the parametric model did not. The differential effects revealed that ZT practitioners could not realise the yield advantage of ZT because of the unavailability of ZT machinery when needed and the prevalence of small fragmented plots. Instead, those who did not continue ZT technology in the following year got higher yields with a minimum number of tillage operations. Because of the predominant practice of cultivating farmland by animal-drawn plough in Bhairahawa, ZT was very effective in reducing tillage costs. Generally, ploughing by animal costs more than by tractor because of the greater labour requirement and longer time needed. In contrast, the expenditure on herbicides was increased in the ZT wheat plots in Bhairahawa because of excessive weed infestation. Nevertheless, we can expect a gradual decline in expenditure with further use of ZT (Vincent and Quirke 2002).

ZT seemed a sound technology for the rice–wheat systems in both regions owing to its remarkable cost savings. This proven technology can lessen the cost of production and reduce turnaround time between rice harvest and wheat sowing, but lack of ZT machinery and technical knowhow can limit the benefits. Some farmers have already noticed the problem of soil compaction due to ZT operations; this could prove a frustration to farmers.

---

4 Karnal and Bhairahawa clusters were selected since they were the project areas of CIMMYT to promote ZT technology on the Indo-Gangetic Plains.
And yet a substantial number of farmers have already been inching towards minimum tillage\textsuperscript{5}, pursuing the yield premium and cost savings with no problems of soil compaction and unavailability of ZT machinery.

**Keywords**

Impact assessment, propensity score matching, India

**References**


\textsuperscript{5} In total 88, farmers already knew about resource conservation technologies, but they did not bring ZT into practice. Nevertheless, they reduced the number of tillage operations by up to 3. but IT practitioners on average practised 5 tillage operations for wheat sowing in a season. On the other hand, only 15 compliers started practising ZT and minimum-tillage in the following year. Seventy farmers fully adopted of ZT in the study sample.
Double planting maize plus ginger in Nepal

Shree Prasad Vista*¹, Kabita Basnet²

¹ Agriculture Research Station, Pakhribas, Nepal Agricultural Research Council, Nepal
² Central Department of Economics, Tribhuvan University, Kirtipur, Nepal

*Corresponding author: prasadvista@rediffmail.com

Remote hill farmers in Nepal have practised conservation agriculture (CA) for a long time without being aware of the concept. At the same time, the diversified farming system adopted by small-scale agrarian communities has helped to preserve natural resources. Crop diversification in the eastern hills of Nepal reduces weeds, pesticide use and labour. The inclusion of pea and soybean in the cropping system enriches the soil and improves the health of livestock. Increased milk yields during the legume stubble feeding period increase family income. The recycling of farm organic waste via livestock results in good harvests. The integration of forage reduces pest incidence and controls soil erosion. The cultivation of marigold (Tagetes) for the Tihar festival in the borders of fields has aided farmers both from income and by restricting pest incidence.

We studied maize plus ginger intercropping under double planting of maize (2 plants per hill) to disseminate the technology in the middle hills of eastern Nepal.

Diamond trials (2 x 2 treatments) were conducted in 2 locations. Maize (single and double planting) and ginger were grown in different combinations (Table 1).

Recommended rates of fertilisers and farmyard manure were added.

The average yield, land equivalent ratio and net benefit were all much higher with maize double planting plus ginger intercropping than in the other treatments (Table 1), as we previously found (Katuwal et al. 2008).

Table 1. Average yield, land equivalent ratio (LER) and net benefit under each cropping system.

<table>
<thead>
<tr>
<th>Cropping system</th>
<th>Average yield (Mg/ha)</th>
<th>LER</th>
<th>Net benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double planting maize + ginger</td>
<td>18.4</td>
<td>1.83</td>
<td>86 250</td>
</tr>
<tr>
<td>Single planting maize + ginger</td>
<td>15.4</td>
<td>1.56</td>
<td>14 634</td>
</tr>
<tr>
<td>Maize alone</td>
<td>5.0</td>
<td>1.00</td>
<td>158</td>
</tr>
<tr>
<td>Ginger alone</td>
<td>15.6</td>
<td>1.00</td>
<td>78 500</td>
</tr>
</tbody>
</table>
Keywords

Maize–ginger integration, livestock, double planting

References

Maize expansion in Xieng Khouang province, Laos: what prospects for conservation agriculture?

Jean-Christophe Castella1,2, Etienne Jobard3, Guillaume Lestrelin1, Khamla Nanthavong1, Pascal Lienhard4

1 Institute of Research for Development, Vientiane, Lao PDR
2 Centre for International Forestry Research, Bogor, Indonesia
3 AgroParisTech, Paris, France
4 CIRAD, Vientiane, Lao PDR

Corresponding author: j.castella@ird.fr

Background

During the 2000s, the rapid expansion of maize cultivation engendered substantial landscape transformations in the Laotian province of Xieng Khouang. Maize not only replaced existing upland crops, including gardens and fruit tree plantations, but also expanded at the expense of forests and fallow lands. This impressive agricultural intensification has occurred as a corollary to the introduction of hybrid cultivars in the region (Jobard et al. 2011). With farmers’ greater agricultural income and investment capacity, mechanical ploughing has become the main technique for land preparation, and herbicides are now commonly used in the cropping sequences (Lestrelin et al. 2012).

With the exception of a few villages with limited potential for paddy rice production, intensive maize cropping has replaced traditional rice-based slash-and-burn techniques in the uplands (Kongay et al. 2010). From 2003 to 2009, the Lao National Agro-Ecology Programme (PRONAE) was implemented in the province to mitigate the potential harms of intensive maize monocropping. The project offered technical support to target villages through agricultural extension of direct mulch-seeding cropping (DMC) systems, equipment lending and training on the safe and sustainable use of pesticides.

Objectives

This abstract addresses the impacts of maize expansion on the household economy by comparing 2 series of household surveys conducted in 2003 and 2009 in Kham and Nonghet districts (600 households in 20 villages). We analysed the contribution of maize to local incomes over time by comparing observed household income changes with simulated household incomes under the hypothesis of no maize expansion. Despite low adoption rates in the target zone of PRONAE, we also explored the potential impacts of DMC systems on the household economy.
Methods

**Village selection.** In 2003, 73 households in Xieng Khouang province were surveyed by PRONAE. The same households were surveyed again in 2009 so livelihood changes could be detected.

**Village census.** All 1463 households in 20 target villages were surveyed to gather basic information on the structure of the households and farms. The data were used to build a typology of households and to select stratified samples for more surveys.

Rapid household surveys were then undertaken in 600 households (30 random samples in each target village). These rapid surveys gathered data on changes to farming system (crops and livestock) and livelihood (assets and housing) and the extent of adoption of DMC systems since 2005.

Detailed socioeconomic surveys of 10 households per target village addressed the decision-making processes of the farmers in relation to the transition from subsistence to commercial agriculture and to the adoption of DMC techniques. Qualitative data were also collected through focus groups on the drivers of change (e.g. access to technical information, markets and credit) and perceived changes in the environment and security of land tenure.

Data management and analysis. All data were entered in a database, and statistical analyses and socioeconomic modelling were performed. Olympe software was used to explore the future of maize productivity under intensive versus conservation agriculture (CA) practices.

Results

Five main household types were identified in 2009 (Table 1) and compared with their 2003 situation. Better-off households in 2003 had kept their economic advantage in 2009 through early investment in maize cultivation. The replacement of upland crops by maize led to a general improvement of economic situation (Fig. 1).

More generally, the local patterns of household differentiation during the maize boom appeared to be directly related to the availability of upland area and capital (Fig. 2a).

As a result of PRONAE extension activities, DMC systems covered a small proportion of the total upland areas cultivated in the target area in 2009. The highest DMC adoption rates were encountered among medium-range household types, reflecting a strategy of lessening the investment risks while optimising the returns on labour (Fig. 2b).

However, the cropping model that really imposed itself is the one based on soil tillage (Nanthavong et al. 2011). DMC had more success on the hillsides, where the steep slopes prevented heavy mechanisation. Thus, while the status of CA appears rather unsettled in the area, farmers with sufficient capital tended to shift from slash-and-burn or DMC systems to ploughing-based systems (Lestrelin et al. 2012).
Figure 1. Changes in return on land and return on labour of the main cropping systems.


Figure 2. Principal component analysis linking household types with (a) increasing capital availability and (b) the percentage of maize under DMC.
Table 1. Household typology in 2009.

<table>
<thead>
<tr>
<th>Household type</th>
<th>Main characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1A</td>
<td>Rice needs covered by lowland paddies. Rice surpluses invested in livestock and off-farm activities</td>
</tr>
<tr>
<td></td>
<td>Upland areas all cropped with maize—labour force availability limits maize expansion; use of mechanised tillage contractors</td>
</tr>
<tr>
<td>Type 1B</td>
<td>Limited lowland areas. Upland rice cropped to reach rice sufficiency</td>
</tr>
<tr>
<td></td>
<td>All remaining upland areas (besides upland rice slash-and-burn system) are cropped with intensive maize</td>
</tr>
<tr>
<td>Type 1C</td>
<td>No paddy land. Rice sufficiency reached with upland rice only</td>
</tr>
<tr>
<td></td>
<td>Family labour force fully occupied with upland crops. Herbicides used to expand area under maize cultivation</td>
</tr>
<tr>
<td>Type 2A</td>
<td>Maize production on 100% of the farm land; sold to buy rice for household consumption</td>
</tr>
<tr>
<td></td>
<td>Intensification of cropping practices (mechanical tillage + herbicide) because of lack of labour to expand upland agriculture</td>
</tr>
<tr>
<td>Type 2B</td>
<td>No paddy land. Upland rice cultivation is a risk management strategy in case of bad maize harvest</td>
</tr>
<tr>
<td></td>
<td>Maize on hillsides is not mechanised. Limits economic risks but places high demand on family labour</td>
</tr>
</tbody>
</table>

Discussion

With tillage, herbicides, pesticides and hybrid seeds, farmers have significantly reduced the time spent in their fields, which seems to be a key consideration for all household types. Yet with the gradual homogenisation of landscapes and production, farmers have also become more vulnerable to land degradation, agrobiodiversity loss and price fluctuations. Although DMC systems provide possible ways to solve long-term drawbacks resulting from the dynamics of land use intensification in the study area, they may be associated with higher requirements for labour (e.g. sowing and management of legume cover crops) and finance (e.g. fencing to protect cover crops and residues from communal grazing).

It is difficult to encourage local farmers to take a long-term perspective, even though most are aware of the potential drawbacks of their practices on the environment and on their future agricultural production (Keophosay et al. 2011).

To date, they have not experienced any environmental degradation. Therefore, they do not perceive any need to change their current cropping practices. Farmers are reluctant to experience an immediate loss in their income or in their return on labour despite the recognition of the potential loss in the long term (Fig. 3).
Conclusions

Without experience or knowledge of the potential downsides of intensive maize monocropping, farmers do not feel the need to invest time and capital in alternative cropping systems. Indeed, all environmental costs of prevailing cropping systems are currently externalised, and the environmental benefits of DMC systems are not accounted for in economic evaluations.

Prospective analyses and simulations are required to explore scenarios with multiple stakeholder groups and to design support policies for more sustainable agricultural practices. As long as the environmental drawbacks of intensive agriculture are not perceptible by local farmers, only strong policy incentives and regulations (e.g. bans on mechanical ploughing on steeply sloping lands), combined with extension activities conducted in close collaboration with research agencies, can prevent the rapid expansion of unsustainable practices.

Keywords

Farming systems, innovation adoption, risk management, prospective simulations, Lao PDR
References


Chapter 6

Conditions, strategies, barriers and opportunities for scaling-up conservation agriculture

Vietnam
Mulch preparation with a locally-designed roller

T. Xuan Hoang, Son La, 02/2012
Global concerns regarding poverty and food insecurity, environmental degradation, rising costs of production, climate change and the unsustainable tillage-based production paradigm offer opportunities for scaling up conservation agriculture (CA) systems that are based on the 3 interlinking principles of minimum soil disturbance, maintenance of soil cover and crop diversification. At present, there are some 125 million ha of arable crop land under CA, corresponding to about 9% of the global cropland, spread across all continents and agro-ecologies. The barriers to the adoption of CA that must be overcome include intellectual, social and physical insufficiencies of equipment and mechanisation, and the need for policy and institutional support. This paper elaborates on the conditions that appear necessary for CA adoption and uptake, and on elements that need to be considered in the design and implementation of policies and institutional support strategies to scale up CA.

1. Introduction

Conservation agriculture (CA) is defined as a production system in which crop, soil, nutrient, pest, water and energy management components and operations are based on a sustainable ecological foundation provided by three interlinking principles: (1) minimum soil disturbance (no-till direct sowing); (2) maintenance of soil cover (mulch cover from crop residues and cover crops); and (3) diversification (rotations or associations) of crops, including cover crops (FAO 2012).

CA principles can be applied through locally formulated and adapted practices to all agricultural production systems, including broadacre, horticulture, tree crop, plantation, agroforestry, organic and crop–livestock systems with manual, animal-drawn or mechanised farm power (FAO 2011; Kassam et al. 2011).

---

Tillage-based systems can be productive, but they are not sustainable ecologically and economically in the long run, because the rate of soil degradation (from erosion and other forms of loss of soil quality) is generally higher than that of the natural soil formation and self-recuperation capacity (Montgomery 2007). The degradation of the soil follows from the loss of soil organic matter and the associated soil life and structure owing to excessive rates of oxidation resulting from tillage (Reicosky 2001, 2008).

The relevance of CA for international, national and local agricultural development is that, unlike tillage-based systems, it is capable of simultaneously improving crop productivity and ecosystem services such as erosion control, water purification, nutrient, carbon and water cycling, and pest management (Kassam et al. 2009; FAO 2011).

The capacity of CA to improve sustainability should spur innovative policymaking, thinking and action at government levels in the search to revitalise agriculture on all degraded lands of any degree, where increasing expenditures are required just to maintain yields at the average level.

This paper elaborates on some of the opportunities and barriers to CA adoption and uptake that exist internationally, and discusses the conditions that need to be taken into account in designing and implementing policy and institutional support strategies for scaling up CA.

2. Opportunities for adoption and uptake

Major changes in awareness and knowledge have been occurring during the past 3 decades in agricultural development and poverty alleviation, and they can all strengthen the opportunities for promoting the spread of CA to address five major challenges faced internationally, namely:

1. The global concerns regarding pervasive abject poverty and food insecurity for the bottom billion; high prices for food, production inputs and energy; widespread degradation of agricultural land; resource scarcity; and climate change.

2. The continuing high environmental impact of tillage-based agriculture, leading to economically and environmentally suboptimal productivity in rainfed and irrigated agriculture, soil and agro-ecosystem degradation, pollution of water systems due to erosion and to leaching of agrochemicals, and vulnerability to climate change.

3. The shortcomings of the relatively high-cost tillage–seed–fertiliser–credit approach to agricultural development and sustainable livelihoods for the resource-poor small farmers trapped in a downward spiral of land degradation, fragile economies, and ineffective policy and institutional support.

4. The increasing preference for agro-ecologically based production systems that are environmentally more benign, offer both improved productivity from less inputs and greater environmental services, and are ‘climate-smart’ in terms of adaptation and mitigation.

5. The natural and anthropogenic disasters and crises which often lead to emergencies involving large rural populations whose agriculture systems and livelihoods have to be rehabilitated through relief and development measures.
Much has been written about the above global concerns and situations (MEA 2005; WDR 2008; McIntyre et al. 2008; Foresight 2011; UKNEA 2011; FAO 2011). These concerns and situations are creating opportunities for CA to replace tillage-based agriculture, which is increasingly being recognised to be ecologically and economically unsustainable (Shaxson et al. 2008; Friedrich et al. 2009; Kassam et al. 2009; FAO 2011).

CA is underpinned by 3 interlocking principles -minimum soil disturbance, maintenance of soil cover, and crop diversification- that enable producers to intensify production sustainably, improve soil health and minimise or avoid negative externalities. CA is able to support and maintain ecosystem functions, and services derived from it, while limiting interventions (required for intensifying the production) to levels which do not disrupt these functions. Thus, intensification with CA allows efficiency (productivity) gains and produces ecosystem benefits. CA offers benefits to all producers, regardless of scale; to all types of soil-based systems of agricultural production; and to society at large (Pretty 2008; Friedrich et al. 2009; Kassam et al. 2009; Pretty et al. 2011), through:

• higher, more stable production, productivity and profitability with lower input and capital costs
• capacity for climate change adaptation and reduced vulnerability to extreme weather conditions
• enhanced production of ecosystem functions and services
• reduced greenhouse gas emissions.

CA principles translate into a number of locally devised and applied practices that work simultaneously through contextualised crop–soil–water–nutrient–pest–ecosystem management at a variety of scales. The adoption of CA has resulted in savings in machinery, energy use and carbon emissions; a rise in soil organic matter content and biotic activity; less erosion; increased crop water availability and thus resilience to drought; improved recharge of aquifers; and reduced impact of the variability in weather associated with climate change (FAO 2008, 2012). It can also result in lowered production costs, leading to more reliable harvests and reduced risks.

CA has been replacing tillage-based agriculture over large areas, especially over the past 20 years or so in North and South America and in Australia. In the last 10 years, CA has been spreading in Asia and Africa, as well as in Europe. At present, there are some 125 million ha of arable land under CA, corresponding to about 9% of the global cropland, spread across all continents and agro-ecologies (Table 1) (Friedrich et al. 2012), half of it in developing countries. It has been spreading at some 7 million ha a year as more development attention and resources have been allocated by governments, public and private sector institutions, international research and development agencies, NGOs and donors (Kassam et al. 2010; Friedrich et al. 2012).
Table 1. Area under CA by continent.

<table>
<thead>
<tr>
<th>Continent</th>
<th>Area (ha)</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>South America</td>
<td>55 464 100</td>
<td>45</td>
</tr>
<tr>
<td>North America</td>
<td>39 981 000</td>
<td>32</td>
</tr>
<tr>
<td>Australia &amp; New Zealand</td>
<td>17 162 000</td>
<td>14</td>
</tr>
<tr>
<td>Asia</td>
<td>4 723 000</td>
<td>4</td>
</tr>
<tr>
<td>Russia &amp; Ukraine</td>
<td>5 100 000</td>
<td>3</td>
</tr>
<tr>
<td>Europe</td>
<td>1 351 900</td>
<td>1</td>
</tr>
<tr>
<td>Africa</td>
<td>1 012 840</td>
<td>1</td>
</tr>
<tr>
<td>World total</td>
<td>124 794 840</td>
<td>100</td>
</tr>
</tbody>
</table>

3. Barriers to adoption and spread

Farmers in a country or region where sustainable intensification is not practised face a number of diverse problems that make adoption difficult, including intellectual, social, biophysical and technical, farm power, financial, infrastructural and policy constraints (FAO 2008; Friedrich and Kassam 2009).

3.1 Intellectual barriers to adoption

CA has 2 major intellectual barriers to overcome. The first is that CA concepts and principles are counterintuitive and contradict the common tillage-based farming experience. Unless a person has seen it happen, it is very difficult to imagine a soil becoming softer and better structured without being tilled.

The second intellectual impediment to adoption is simply the lack of sufficient experiential knowledge and the means of acquiring it. Globally some 10% of agricultural land is under CA, but while its adoption exceeds 50% in some countries, it falls below 2% in the rest of the world. This explains why most people have never seen a CA system in practice and therefore don’t perceive it as an option. However, once stepwise adoption begins, CA improves performance over time. The more experience producers have with CA, the more convinced and positive they are.

3.2 Social barriers to adoption

Farming communities in the developing regions are mostly conservative and risk averse. Any farmer doing something fundamentally different from the others will therefore risk being excluded from the community. Only very strong and individually minded characters would take that step, which can lead to social isolation and sometimes even to mocking. Even if those individuals have visible success, the aversion created in the community and the peer pressure can result in other farmers not following.
For the adoption of CA it is therefore not enough to find any progressive farmer who will prove the concept to work, but rather a farmer with a socially important role, who is respected and integrated in the community. Ideally the whole community should be involved from the very beginning - in identifying the problems, the proposed changes and expected benefits - to avoid this kind of antagonism.

Other problems can arise from traditional land tenure systems, where there is no individual ownership of land, which lowers the incentives for farmers to invest in the long-term improvement of soil health and productivity. Communal grazing rights, which often include the right to graze on crop residues or cover crops after the harvest of the main crop, can create conflicts which make it difficult for the uptake of CA practices. These problems can be real impediments to the adoption of CA, and conflicts arising from, for example, alternative uses of crop residues as mulch or animal feed cannot be solved by orders or directives. The entire community must first understand the issues and the changes and benefits involved in adopting CA and jointly look for solutions.

3.3 Barriers of lack of farm power, equipment and mechanisation

One of the most important and yet commonly overlooked inputs in agricultural production systems is farm power, whether human, animal or mechanical. Lack of sufficient farm power in many countries is a bottleneck to increasing and intensifying production, especially where it depends on manual or animal traction power (Friedrich et al. 2012; Sims et al. 2011).

Suitable mechanisation options can lead to improved energy efficiency in crop production, leading to better sustainability, higher productive capacity and lower environmental damage at any level of socioeconomic development (Baig and Gamache 2006; Lindwall and Sonntag 2010). Particularly for small-scale farmers, community-based solutions to the farm power problem are often the only way to overcome the prevailing shortcomings. Nevertheless, a start can be made manually, even where there may be a lack of animals, tractors, or appropriate sowing equipment.

3.4 Policy and institutional barriers to adoption and uptake

Adoption of CA can take place spontaneously, but it usually takes a long time until it reaches significant levels. Adequate policies can shorten the adoption process considerably, mainly by removing the constraints mentioned above. This can happen through information and training campaigns, suitable legislation and regulatory frameworks, research and development, incentives, and credit programs.

In essence, the role of policy and institutional support is to ensure that the necessary conditions be met for the introduction and subsequent widespread adoption of CA systems in various agricultural land use sectors.

However, in most cases policymakers also are not aware of CA, and many current policies work against the adoption of CA.
Typical examples are commodity-related subsidies, which reduce the incentives of farmers to adopt diversified crop rotations, mandatory prescription for soil tillage by law, and the lack of coordination between different sectors in the government. Policymakers and legislators must be made aware of CA and its ramifications to avoid such contradictory policies.

An additional problem with the introduction of CA is that by policymakers do not recognise the building up of soil organic matter under CA as an investment in soil fertility and carbon stocks. Some policy instruments are required in order to hold the land owner responsible for maintaining the soil fertility and the carbon stock in the soil (which in absence of agricultural carbon markets is difficult to achieve). Generally, farmers with secure land tenure are more likely to take care of their land and maintain or increase the stock of carbon in the soil.

Development policies generally need public sector institutions to implement them. In the case of CA, policy implementation should involve the alignment and empowering of extension, research, education and training institutions in the promotion of CA through all the normal development channels. Similarly, private sector institutions responsible for input supply would also need to align themselves towards the promotion of CA; likewise NGOs and donor agencies who are engaged in promoting agriculture development. Typically, the public, private and civil sectors are generally aligned to the current norms of tillage-based agriculture in agricultural development. Thus, scaling up of CA adoption means a change in the mindset of those who practise agriculture and in the very culture of agriculture.

4. Conditions and strategies for scaling up CA

In general, scientific research on CA lags behind farmers’ own discoveries (Derpsch 2004; Bolliger et al., 2006; Goddard et al. 2008). Similarly, knowledge and service institutions in the public and private sectors tend to be aligned to supporting intensive agriculture (IA). Further, there is limited policy experience and expertise to assist in the transformation of IA to CA for small- and large-scale farmers in different ecologies and countries (Friedrich & Kassam 2009; Milder et al. 2011; FAO 2011).

The typical adoption of successful new concepts and technologies follows an ‘S’ curve, with a slow start to adoption (possibly preceded by farmers’ own trials), then exponential growth and a final slowing down towards a plateau (Alston et al. 1995; Rogers 1995).

It can be postulated that in most countries CA is being introduced as an ‘unknown’ new concept, and that there is no agronomic knowledge base or policy and institutional support for the adoption of CA.

The reasons for farmers to change from one production system to another vary according to location, but in most cases erosion problems, weather problems (drought) and unfavourable profit margins are the most important motivations for farmers.
4.1 Conditions for CA adoption and uptake

The adoption of CA is a process of change and adaptation based on experiential learning over time.

The support to foster the necessary conditions -the ‘enabling environment’- for the introduction of CA and the transformation of IA systems towards CA systems must be mobilised at the individual, group, institutional and policy levels within the private, public and civil sectors for adoption and spread. If this is not achieved, CA might be dropped.

4.1.1 Reliable local individual and institutional champions

Wherever CA has been successfully introduced or its spread is making steady progress, there have been local champions -usually farmers- whose own examples have encouraged the process.

Local and national champions, both individuals and institutional, are now being supported increasingly by international champions. Such champions are an absolute necessity to promote and sustain the adoption of CA and subsequent on-farm innovations, and must operate in all production subsectors at all levels if CA practices are to become mainstream globally.

4.1.2 Dynamic institutional capacity to support CA

CA is a dynamic system in constant development and adaptation. The institutions that are set up to support CA need to be similarly dynamic so that they can respond to farmers’ varied and changing needs. As well as policymaking departments, these institutions include the R&D programs on which much of the technical knowledge of CA is based. Whatever technological combinations farmers use, R&D activities must help to ensure that good husbandry of crops, land and livestock (Shaxson 2006) can occur simultaneously for the system to function well.

Biophysical, ecological, agronomic and social sciences must be combined with the views of stakeholders to develop systems that can be adapted to varied conditions facing farm families. This means that the diverse providers of information need to be involved in broad programs to develop the science and technology for CA. Such institutions include international agencies, multi-donor programs, NGOs, national government staff, academic institutions, commercial organisations and agribusiness.

4.1.3 Engaging with farmers

Support for any production systems, whether CA or otherwise, must be oriented towards solving the problems that inhibit productivity. Farmers need support to understand and absorb new concepts and principles and so enable an intellectual change in the mindset to CA. Thus, engaging with farmers and providing them with the necessary support is critical for the successful adoption and uptake of CA.
(a) The importance of working with farmers

Helping farmers to improve the husbandry of land through CA must start with a thorough understanding of the present situation, of which the farmers themselves have the most detailed knowledge (FAO 2001a). From the outset, they must be the deciders of what is to happen once the root causes of land degradation and suboptimal production systems are understood. Farmers must be the principal point of focus, as they make the decisions about how the land is used and managed.

Sufficient attention also needs to be given to enablement, such as through rural finance, service and input supply infrastructure, marketing and value-chain development, and organisational or policy issues. Changing over to a new system and ways of doing business carries a perceived and sometimes real risk of failure, and this aspect must be taken into account in the initiatives that are designed to promote and help the transition towards effective CA.

Farmers can be ingenious in problem solving, and if they pick up the conceptual part of CA, they may well innovate and adapt the practices to their own conditions (WOCAT 2007).

(b) Importance of farmers’ organisations

Farmers tend to believe trusted peers more than their formal advisors when discussing innovations. Making it easy for them to exchange ideas and experiences helps strengthen their own linkages and reinforce recommendations.

Farmer participation in technology development and participatory extension approaches have emerged as responses to such new thinking (Pretty et al. 2011). Interested farmers may have already coalesced into informal groups with common interests. Such groups can form the basis for farmer field schools, with guidance from experienced advisors, for ‘learning by doing’ (e.g. Mariki et al. 2011).

The fastest development of suitable technologies is usually achieved through groups of innovative and pioneer farmers who are part of a community and exchange their experiences through specific networks, and thus build social capital (Meyer 2009; Junior et al. 2012).

4.1.4 Providing knowledge, education and learning services

CA involves a fundamental change in the way agricultural production is conceived and how it relates to environmental stewardship (Kassam et al. 2009) at the farm, national and international levels.

One necessary change is to inculcate in schoolchildren -and then right up through graduate and postgraduate education -the opportunities for a broader focus on ecologically based, resource-conserving agriculture based on the core CA principles in all settings for sustaining the production of crops and water from landscapes, and for protecting the environment and biodiversity.
Both researchers and advisory staff need to be kept up to date with the different ways by which the principles of CA are put into practice in different agro-ecologies, their effects on the resource base and the environment, and socioeconomic results. This means having the capacity to work across the traditional science disciplines and to work closely with farming communities. Recognising the realities of CA technical education and vocational training in universities, colleges and schools will include CA principles and benefits in their curricula. Such training would stress the commonality of the principles of good land husbandry as expressed in CA and show how they can be applied through diverse technologies and development approaches.

Research and extension need to be able to operate at different scales simultaneously. They need to be able to assess the landscape-scale benefits of adopting CA while also providing evidence of how well CA performs on individual landscape units, farms and farming communities.

(a) There is need to enable scientists and extension agents to recognise and characterise the problems related to CA adoption and facilitate problem solving.

(b) There is need to build up a nucleus of knowledge and learning systems for CA in the farming, extension and science communities.

4.1.5 Mobilising input supply and output marketing sectors for CA

With farmers grouping together into associations, potential suppliers of inputs and technical advice will become aware of potential commercial opportunities, and can be encouraged to join in and provide supplies to the farmers. Usually some ‘kick start’ is necessary to break the deadlock of farmers not adopting because of lack of available technologies and equipment and the commercial sector not offering these technologies for lack of market demand. Policies facilitating procurement with credit lines, promoting technologies with technical extension programs and introducing supportive tax and tariff policies are important for building up the long-term commercial development of suitable input supplies for CA.

Arrangements for marketing the crops and for selling farm inputs require attention at the time of beginning the CA revolution in a country where these may not work well. This has implications for improving the bringing together of suppliers and purchasers to work as a team with government field staff and others in responding to farmers’ needs and requirements.

(a) Ensure accessibility and affordability of required inputs and equipment.

(b) Financing and enabling the initial stages.

4.2 Bases for designing and implementing policy and institutional support strategies

Having made a commitment, it is important for a government to make a policy that will ensure that sufficient and appropriate support to farmers’ efforts be provided and maintained, so as to share costs and risks taken by small farmers during the period of changeover.
This period might be up to 5 years until farmers develop full confidence in managing the new system. Because uptake would not all occur at the same time, such assistance would necessarily be needed on a ‘rolling’ basis.

Finance should be available for study tours, field days and other opportunities for farmers to meet each other and discuss CA matters of mutual interest as a potent way of stimulating innovations; for example:

- benchmark demonstration areas for CA
- staff training on CA principles and modes of application
- field days and study visits for farmers
- participatory and interdisciplinary learning for CA development
- operational research with farmers as partners.

Effective demand in the market and the value chains beyond production are also important in ensuring that farmers can receive an attractive return for their efforts to produce safe and nutritious food and other ecosystem products. Policies and institutions that encourage and enable the integration and verification of CA practices and their products into practical programs in which farmers can receive monetary benefits for delivering certain ecosystem services need to be established.

4.2.1 The need to sensitize policymakers and institutional leaders

Both the field demonstrations and technical discussions generated by the growing spread of CA methods and successes, as told by farmers and others, will also make government department heads, policymakers, institutional leaders and others aware of the benefits, and of the desirability of backing the initiatives. It is important that policymakers come to a full understanding of the implication of the CA system. This makes it easier for them to justify supportive policies, which in the end are beneficial not only for the farming community, but also for everyone, including the policymakers and their constituency. On the other hand, it is important for policymakers to think in long-term developments and in integrated approaches, even across sectors and ministries (Pieri et al. 2002).

4.2.2 Formulating enabling policies including for rapid scaling up

Although it is not possible to distil a generic set of policy and institutional support guidelines that could constitute initial interventions for promoting the transformation towards CA systems, an effective sequence of strategic actions could be as follows:

1. Identify the limiting factors to farmers’ improving their livelihoods (which may not always be primarily financial) to catch their attention.
2. Identify factors limiting crop yields and what could be done to alleviate them.
3. Identify one or more farmers already practising CA and demonstrating its agronomic, financial and livelihood benefits, and set up study visits.
4. Set up demonstration for researchers and advisory staff and farmers’ groups leaders, to catch their interest.
5. Initiate ‘learning by doing’ such as through participatory forms of investigation and learning. Gain insight into what farmers know already and how they would tackle the apparent problems in the light of new knowledge introduced.

6. Determine the optimum means of achieving CA’s benefits for different situations of farm size and resource endowments through on-site research and benchmark demonstration, observation, farmer field schools and field days on farms already attempting CA. Record keeping, analysis and feedback loops, and operational research are all important.

7. Importing suitable samples of equipment (e.g., jab planters, direct seeders for animal or tractor power, knife rollers, walking tractors with no-till seeder attachments) to be able to demonstrate their use at the beginning.

8. Interact with any already established farmers’ groups, e.g. cooperatives, to gain interest and support.

A facilitating policy environment can be an important determinant of whether CA is adopted or not and how fast. In cases where policy has been weak or ineffective, much of the successful diffusion of CA has occurred because of support from the private sector, farmers’ groups or other non-governmental organisations. In some countries, existing policies have both encouraged and discouraged CA at the same time.

While CA so far has spread mostly without policy support, it would need a supportive policy environment for accelerated spread. However, there is no ‘one size fits all’ policy in support of CA: whether this comprises direct interventions, indirect incentives via R&D or a mix of the two. Since the principles of CA are based on an understanding of farm-level biophysical and socioeconomic conditions, farm management objectives, attitudes to risk and the complementary relationship between stewardship and profits, policies in support of CA need to be formulated on a similar appreciation.

The main implication is that most policies to support CA adoption and spread must be enabling and flexible, rather than unitary and prescriptive. Allowing the design of location-sensitive programs which draw on a range of policy tools would ensure that the design of policies which both accommodate and promote the location-specific nature of CA and its on-farm and landscape-level benefits (Pretty 2008; Kassam et al. 2009; FAO 2011; ECAF 2012; Kassam et al. 2012).

However, one area where a more uniform policy may be appropriate is in the development of social capital, to promote the precursor conditions for collective action—such as the development of group extension approaches (FAO 2001b) when dealing with smallholders who are operating in poverty with a degraded resource base and poor access to markets.

Within this flexible policy framing, however, policymakers need to consider 5 other issues:
1. ‘Sustainability’ as justification for policy support for rapid scaling up: the capacity of CA to specifically address the improvement of sustainability -through improved functioning of its biological components- should spur innovative thinking and action by government in the search to revitalise agriculture on all degraded lands of any degree.

2. Policies relating to farm-level risk management, especially associated with the time of making the switch from IA to CA, and thus to the generating and sustaining of associated environmental benefits.

3. Basing macro-level landscape management policies on understanding of micro-level realities about, for example, soil conditions and farming systems.

4. Compatibility between relevant policies (‘policy coherence’), to enhance positive synergies between policies which affect farmers’ and others’ decision-making in favour of initiating and developing CA.

5. Policies to actively encourage knowledge sharing—vertically (between different levels of government and of other relevant institutions) and horizontally (within and between different farmers, researchers, advisory staff, NGOs and other stakeholders).

4.2.3 Putting a political emphasis on policy and institutional support

In general, unless they result in catastrophic dimensions of erosion and cross-border ‘dust plumes’, soil health and soil productive capacity do not inspire or attract policymakers. On the other hand, marshalling facts and experiences about benefits, both social and technical, as positive contributions towards alleviation of current problems, and to avoidance of future problems, are likely to garner more enthusiastic political support.

5. Concluding remarks

CA represents a more secure paradigm of agriculture than IA, and so deserves closer attention because of its implications and possibilities for spread.

CA is not spreading quickly in Africa, Asia and Europe because of a lack of general knowledge and understanding about CA, of a supportive enabling environment for its promotion, of the fact that both public and private institutions serve mainly IA. However, the increased adoption of CA in these continents during recent years indicates that the situation is changing, and the uptake of CA should accelerate.

There are a number of good reasons why farmers do not immediately and spontaneously adopt CA, despite the acknowledged advantages. Farmers first have to overcome a number of hurdles. Foreseeing these hurdles and problems allows the development of strategies to overcome them. Crises and emergency situations, which seem to become more frequent under climate change scenarios, and the political pressures for more sustainable use of natural resources and protection of the environment on the one hand, and for achieving food security on the other, provide opportunities to harness these pressures for supporting the adoption and spread of CA and for helping to overcome the existing hurdles to adoption.
Thus, actual global challenges are providing at the same time opportunities to accelerate the adoption of CA and to shorten the initial uptake phase. However, most changes occur gradually, and so we must recognise the need for a fundamental change. Agencies must increasingly align their work in research, education and extension to understand the root problems and the role that CA can play, and then formulate policies for accelerated adoption. Research in particular must help to solve farmer and policy constraints to CA adoption and spread (rather than comparing CA with IA, which is of only academic value).

There is growing evidence from farmer fields, landscape-based development programs and scientific research across all continents that CA improves productivity, profit and the environment. As the full benefits of CA take several years to fully manifest themselves, fostering a dynamic CA sector requires an array of enabling policies and institutional support over the long term, including the availability of necessary inputs and equipment and the fostering of farmer-driven innovations. Undertaking these improvements will enable governments, civil institutions and farmers to progress together.

**Keywords**

Tillage, productivity, ecosystem services, adoption, institutions, policy

**References**


Junior RC, de Araújo AG, Llanillo RF. 2012. No-till agriculture in Southern Brazil. Factors that facilitated the evolution of the system and the development of the mechanization of conservation farming. FAO and IAPAR.


Meyer T. 2009. Direct seed mentoring project final report. Spokane County Conservation District, WA, USA.


Adoption of conservation agriculture by small-scale farmers in southern Honduras

Allan J. Hruska* and Luis Álvarez Wlechez

1 Food and Agriculture Organization, Sub-regional Office for Central America, Panama

*Corresponding author: allan.hruska@fao.org

Small-scale farming in Central America is characterised by farming basic grains, notably maize (Zea mays L.), beans (Phaseolus vulgaris L.) and sorghum (Sorghum bicolor (L.) Moench.), on steep hillsides by peasant farmers using traditional methods of burning crop residues, ploughing with little regard to soil erosion (often with oxen) and hand planting. Predictably, these practices result in severe soil erosion and decreasing yields over time. Despite the efforts of governments and development agencies to change these traditional practices, few positive results have been achieved. One notable exception is that in Lempira Sur, in southern Honduras, where peasant farmers have practised conservation agriculture (CA) for over 20 years. Small-scale farmers in this region have widely adopted CA based on direct sowing into crop residues and elimination of burning before planting, along with occasional inclusion of trees in the fields of maize and beans (Welchez and Cherrett 2002). Although a few reports document this case, no comprehensive, retrospective reviews have been written about the contribution of one of the original promoters of CA in the region.

To understand the reasons for this unusual success, we conducted field interviews with farmers and key informants in the region and with governmental and development organisations. Reports documenting this case were reviewed and data were re-examined. Direct experience in the field contributed greatly to insights into the key factors used. Key factor analysis was used to determine important lessons that are applicable to other cases.

CA as practised by over 6000 peasant farmers in southern Honduras has the following key elements:

1. No slash and burn, through management of natural vegetation.
2. Permanent soil cover through continual deposition of biomass from trees, shrubs, weeds and crop residues.
3. Minimal disturbance of soil through no tillage, direct sowing and reduced soil disturbance.
4. Efficient use of fertiliser through appropriate timing, type, amount and location of fertilisers.
Although the long-term impacts are still being studied, compared with conventional practices in the region, CA has shown positive effects on soil fertility and soil organic matter (Fonte et al. 2010) and on crop yield and water availability (Welchez et al. 2008).

Beyond the positive effects on soil conservation, the experience provides valuable lessons for how to work closely with small-scale farmers and their associations to promote large-scale adoption of sustainable agricultural practices.

While the adoption of CA practices has been well documented among large-scale producers in Latin America (Kassam et al. 2009), few detailed analyses examine the lessons learned from large-scale adoption by small-scale farmers in Central America.

Key to the large-scale adoption of CA in southern Honduras was the role played by local farmers’ organisations and support from local government. Once the farmers and their organisations owned the process, they were able to exert pressure on their neighbours in ways that no outside organisation can achieve in a sustainable manner.

This paper updates the analysis of the adoption of CA practices during the last 10 years, providing data on the extent of implementation and an analysis of the main drivers of implementation, especially in the light of the poor implementation of other CA practices among other groups of farmers in Central America. These lessons are important for farmers, farmers’ associations, extension services, researchers, local and district government officials, policy makers and international funders.

Keywords
Small-scale producers, uptake, Central America, case study

References


Policy for the adoption of conservation agriculture in Mexico

Matthew Fisher-Post*1

1 Master's student, Cornell Institute for Public Affairs, Cornell University, 294 Caldwell Hall, Cornell University, Ithaca, NY 14853, USA
Current address: Cda Guillermo Prieto 11, Depto 502 B, Col. Jesús del Monte, Huixquilucan, Estado de México, México 52764

*Corresponding author : mhf56@cornell.edu

One of the goals of the Mexican government’s agricultural programs is to help Mexican farmers who face diverse challenges, such as low yields, depleted soil health, high input costs, resource scarcity and labour shortage. Any of these conditions could serve as a stimulus for the adoption of soil management practices such as minimum tillage, residue retention and crop rotation, collectively known as conservation agriculture (CA).

Aside from its potential profitability for individual producers, CA has positive environmental benefits, bringing a net benefit to society. By adopting CA techniques and technologies, farmers can contribute to public goods such as the long-term sustainability of soil and water resources, reduced chemical pollution and reduced greenhouse gas emissions.

CA is not entirely new in Mexico. For several decades, social actors in Mexico have been promoting similar practices in soil conservation and management to confront Mexico’s rampant erosion and declining soil fertility. Prominent extension campaigns have focused on 2 practices in particular: minimum tillage and green manure cover crops. This study reviews case studies in the transfer of these technologies.

The purpose of this study was to review how government and social actors have supported (and can support) the adoption of CA. Significant research has investigated the factors influencing the adoption (and non-adoption) of CA, in Mexico and elsewhere. I hope to synthesise a discussion of Mexican farmers’ decision-making considerations in tillage, residue and retention, with an analysis of third-party intervention (government or private extension) in soil management. Therefore, this study focuses on interventions that have changed farmers’ soil management practices in Mexico.

Semi-structured interviews with researchers, farmers, technicians and public officials give weight and authority to the exercise. Their perspectives will help generate conclusions on appropriate intervention (programs and policy) in the scale up of CA.
A review of literature that highlights several interventions from the past 25 years in conservation tillage and cover cropping reveals several of the more important factors in the adoption (and non-adoption) of soil-conserving techniques. The successes and failures of these extension case studies frame conclusions on appropriate extension and technology in the promotion of CA.

From primary sources and a compilation of secondary sources on extension programs in the transfer and adoption of soil conservation practices, I hope these case studies will prove useful for the promotion of CA.

This literature review focused on programs that promoted conservation tillage and green manure or cover-cropping, but the case studies are relevant (and closely related) to the promotion of CA-based crop management. The review examined farmers' adoption decisions according to social, economic and geographic variables, in order to draw conclusions on the appropriate promotion and adaptation of these changes in soil management. The analysis hinges on the opportunity costs and agronomic risks in the adoption of these new management systems. Case studies from reduced tillage and cover cropping campaigns illustrate the contextual variability of costs and benefits. These farmers’ considerations will be useful if we wish to design a public intervention that rewards CA adoption.

**Keywords**

Extension; soil management

**Bibliography**


Sayre K. Personal communication, 20 Aug 2012.
Conservation agriculture in DPR Korea: opportunities and challenges

Pralhad Shirsath*1, Antony Penney1, Jon Dong Gon1
1 Concern Worldwide, DPR Korea

*Corresponding author: pralhadshirsath@gmail.com

The total land area in North Korea (DPRK) is about 122 543 km², of which an estimated 17%, or about 2 million ha, is cultivated by cooperative farms. The inability of the Public Distribution System (PDS) to deliver adequate food rations following the 1990s famine, combined with the loss of employment arising from many factory closures, has generated chronic household food insecurity for many groups. Certain groups, particularly urban women and the elderly, have been forced therefore (or perhaps been informally allowed) to cultivate land with slopes exceeding 15°. This cultivation has caused the deforestation of about 350 000 ha of sloping land to be deforested in 2008 (WFP/FAO 2011). The loss and degradation of natural and environmental resources as a result of the cultivation of sloping land is continuing, as demonstrated by the increased incidence of flooding, landslides and soil fertility loss.

Chronic household food insecurity is therefore causing the loss and degradation of natural and environmental resources, which in turn exacerbates household food insecurity. The solution would be to sustainably protect the resources while simultaneously increasing their productivity.

Concern Worldwide (locally known as European Union Programme Support Unit 3) has implemented conservation agriculture (CA) projects with financial and technical support from the EU and the government of Ireland. The ‘Food Production on Sloping Land’ project, implemented from October 2008 to April 2011 through local government, increased in production diversity from 4 crops to 12 crops. Targeted farmers from cooperative farms adopted CA (based on the principles of minimal soil disturbance, permanent soil cover and crop rotation) on more than 100 ha. This adoption resulted in crop yield increases of 10% to 20%, a halving of per-hectare labour days and an 80% reduction in soil erosion (Wagstaff 2011). A drought in April to June 2012 significantly reduced yields of non-CA crops, but the losses in CA maize fields were negligible.

The DPRK government has a policy to promote organic farming and protect sloping lands, so CA fits well with this policy. CA is therefore being promoted by the Ministry of Agriculture, the FAO and the Academy of Agricultural Sciences in order to spread the practice to other farms in different agro-climatic zones.
Currently, however, CA is practised only in a small area, while the cultivation of sloping land is extensive and increasing rapidly.

There are several barriers to CA adoption and expansion. Competition among fodder, mulch and fuel leaves insufficient crop residues. Energy-saving stoves may be provided to households to allow more crop residue to be used for animal feed or for crop production.

Key constraints to CA development are inadequate mechanisation and herbicide use, due mainly to government budgetary constraints. For example, the Chollima tractor is too unwieldy on uplands and is too wide for the 80-cm intercropping/double-cropping system. Single-axle walk-behind tractors could instead quickly and cost-effectively lead to CA adoption on uplands.

Access to information and cross-learning in DPRK is limited. This highlights the importance of developing different models for different agro-climatic conditions and for meeting local needs in order to scale up CA. It is also important that the government take the initiative to develop policies to ensure that farmers cultivating sloping lands are responsible, extension workers are capable and research institutions be developed.

**Keywords**

Sloping land, erosion, North Korea

**References**

Institutional framework to boost the adoption of conservation agriculture in small-scale farming - lessons from northern Cameroon

O. Balarabé*1, O. Husson2, S. Boulakia3, F. Tivet2, A. Chabanne2, L. Seguy4

1 IRAD/SODECOTON, BP 302 Garoua, Cameroon
2 CIRAD, UPR SIA, F-34398 Montpellier, France
3 CIRAD, UPR SIA, 54B, Street 656, Khan Toul Kork, Phnom Penh, Cambodia
4 AGROECORIZ, Limoges, France

*Corresponding author: obalarabe@yahoo.fr

Conservation agriculture (CA) is practised on only 117 million ha worldwide, or about 8% of arable land. It is practised mainly on large-scale commercial farms in the temperate environments of North and South America, Australia, northern China and some European countries. However, small-scale farmers in tropical regions of Sub-Saharan Africa, South Asia, South-East Asia and Central America have not adopted CA on a large scale (Giller et al. 2009). This differential adoption is related to constraints observed in small-scale agriculture, such as poor definition of property rights and limited access to inputs, credit and information (Erenstein 2003). In addition, focusing only on agronomic factors in designing CA technologies fails to provide suitable solutions for their final adoption and extension. Combining institutional principles based on sociocultural and organisational innovations with agronomic principles is essential (Lahmar et al. 2012).

Current activities promoted by CIRAD in designing and adapting CA technologies rely on a research and extension framework (Seguy et al. 1996) based on different objectives and scales of intervention, which are essential for a detailed understanding of the dynamics of change. This study addressed additional institutional constraints to CA adoption in small-scale agriculture. It also focused on defining priorities among scales (plot, farm, village community), interactions between agronomic and institutional innovations, and other issues. The main objectives were to define the principles of CA adaptation by small-scale farmers through institutional innovations; to define the practical content of the conceptual framework at each scale; and to provide empirical lessons based on indicators and conditions in northern Cameroon.

The study considered both agronomic and institutional issues in CA adoption. It studied innovation through both agronomic and socioeconomic frameworks. It also addressed scale, which is relevant in understanding innovations combining technical and institutional components.
Through its empirical approach, the study provides a conceptual framework on innovation, based on empirical and contrasted situations, unlike most studies of innovation, which rely on theoretical lessons.

The study’s qualitative approach to research (Eisenhardt 1989) relied mainly on case studies in northern Cameroon. The complex definition of property rights in northern Cameroon and degrees of access to inputs and credit make it possible to assess different situations.

A sample of villages and farms were identified as representatives of different examples of property rights and access to credit, and key questions related to different issues of CA adaptation were asked.

Five main principles of CA adaptation through institutional innovations were identified:

1. Recognising that CA technologies should be site specific, and institutional arrangements (local collective agreements) have to change, in relation to the need to sustain natural resources; and the potential of innovations to increase individual and collective benefits.
2. Providing global support for constraints ranging from individual to collective.
3. Producing additional biomass for different uses and bringing together stakeholders to define the distribution of economic costs and benefits related to changes in biomass production.
4. Supporting the supply of input, credit and information related to CA innovation.
5. Providing a broad range of options to smallholders and extension staff to adjust the systems in line with changing market demands, technical constraints and financial capacities.

The study also identified specific priorities, objectives and contents of agronomic and institutional innovations at scales ranging from plot to farm to village. The priorities consist broadly of adapting agronomic innovations at the field scale by designing CA practices to improve soil fertility and to advance sustainability. At the farm household scale, innovations relate to input and credit access. CA technical options will be selected and tailored to fit the contexts and conditions of the farms. Adaptation at the farm scale also has to deal with specific farm enterprises. Collective institutional arrangements related to the management of residues are made at the village level, considering local practices and their collective improvement. Crop–livestock interactions, in addition to being considered in the allocation of resources between competing objectives on farms, are addressed at this level, particularly in the open grazing context of Sub-Saharan Africa.

Finally, to empirically assess CA-based farming systems, additional variables considered included individual and global biomass production and preservation, in addition to crop yield. This consideration made it clear that qualitative information is important to institutional innovations. Data provided by monitoring farm household and pilot villages will make it possible to reinforce the stated principles.
Keywords

Institutional innovations, R/E framework, village community, farm household, plot scale

References


Conservation agriculture extension among smallholder farmers in Madagascar: strategies, lessons learned and constraints

Rakotondramanana*1, Tahina Raharison1, Frank Enjalric2

1 Groupement Semis Direct de Madagascar (GSDM), Lot VA 26 Y Ambohipo, route d’Ambohipo, Antananarivo (101), Madagascar
2 CIRAD, UPR SIA, Ampandrianomby BP 853, Antananarivo (101), Madagascar

*Corresponding author: tahinarison@yahoo.fr

Conservation agriculture (CA) extension in Madagascar has been followed and assessed by a Malagasy organisation, GSDM, with the support of the Ministry of Agriculture and funding from l’Agence Française de Développement. GSDM is a non-profit organisation involved in coordination and monitoring of extension, training and research, and gathering and disseminating information. This abstract presents data held in databases of all institutions and projects involved in CA extension. The issues presented were discussed during an international symposium on CA in Madagascar in December 2010, which was attended by most stakeholders in CA in Madagascar, in addition to FAO, CIRAD and IRD, and during subsequent workshops in 2011 and 2012, in particular during meetings of the National Conservation Agriculture Task Force of Madagascar. GSDM forms the core of the Task Force, which has been supported by FAO since 2009 and is linked to the Conservation Agriculture Regional Working Group within the Southern African Development Community. GSDM coordinates CA.

This abstract analyses the experiences of the main stakeholders in scaling up CA in Madagascar and presents the main recommendations for further actions.

Nearly 80% of the population of Madagascar is rural, involved mostly in the production of rice and other food crops. Soil degradation is severe, on account of various factors, including the nature of the soils, the topography, the aggressive climate, the effects of repeated bushfires and overgrazing.

CA was introduced into the main rice-producing areas of Madagascar to increase smallholders’ income and to protect natural resources. The total area under CA is now about 5000 ha, farmed by roughly 10 000 smallholders [1]. Almost all CA extension has been donor oriented and targeted at rural development and at the protection of catchments and irrigation infrastructure. CA has a proven capacity to increase production, mitigate the consequences of climate change and protect natural resources. CA techniques are promoted in Madagascar to enhance crop production, to combat soil erosion, to conserve biodiversity and as an alternative to slash-and-burn agriculture.
It appears that the adoption of CA in Madagascar has been driven by the need for rice cultivation, forage for livestock, and soil restoration and fertility management.

Rice is the staple food of the Malagasy people, and rice cultivation is the farmers’ main goal. Demographic pressure is reducing the availability of irrigated lands and lowlands, so farmers are interested mainly in upland rainfed crops, and have adopted CA cropping systems able to produce rice. These cropping systems include maize–legume intercropping in rotation with rice, and the use of Stylosanthes guianensis ‘CIAT 184’ as a cover crop. One major driver of CA is the occurrence of the parasite Striga asiatica, which places high constraints on cereal cultivation in the mid-west of the country. This provides an entry point for CA extension [2] and upland rice cultivation after regeneration of the soil with biomass. Pooled results from many farmers’ fields showed that the yield and profitability of CA plots are increasing with the number of years under CA, but labour is often diverted to weeding or cover crop management.

Improving their livestock is an important aim for CA farmers, as CA cover crops are mainly forage or pasture crops. As the cover crops contribute value as feed and soil cover, they enhance livestock and agriculture integration at the farm level. The widespread breeding of zebus is a structural component of the rural population and rural culture. The traditional cover crops grown for fodder in livestock regions are also those most easily adopted in CA. The main need is to determine the trade-off between biomass for CA functioning and biomass for cattle feeding [3].

As most soils in Madagascar are acidic Oxisols with low organic matter content, they are particularly fragile. Soil restoration and fertility management are strategic issues for almost all farmers in Madagascar. CA practices with rotations and legume covers crops can improve soil fertility. The strategy of soil regeneration is seen in various areas, especially in marginal agricultural zones [4].

As in many countries, CA extension faces intellectual, knowledge, social, financial, technical, infrastructural, policy and institutional constraints. Experience across many countries has shown that the adoption and spread of CA requires a change in the commitment and behaviour of all stakeholders [5]. The adoption of CA is a long-term process of change based on experiential learning, with a mechanism to experiment, learn and adapt techniques; and on knowledge sharing (such as by spreading leaflets and technical manuals [6]) in order to implement sustainable and productive cropping systems. According to the 2010 national symposium on CA extension, the main constraints are linked with poor rural infrastructures, insufficient knowledge of CA principles and practices, and poor access to the main inputs.

There are 3 challenges: (1) To build a higher capacity in training at different levels, with priority for training extension staff and government officers. (2) To integrate farming systems and all stakeholders. (3) To streamline CA into national and local policy for rural development through evidence-based CA advocacy.
Lobbying on CA should be targeted at decision makers and, especially, the Ministries of Agriculture, Environment and Forestry, Livestock and Fisheries, Education, Finance and Budget. Coordination of actions between ministries is important, because scaling-up policies should take into account not only the economic and cultural aspects of rural development, but also the ecological aspects, such as the payment for environmental services and the role of CA in managing climate change.

Keywords
Small farmers, scaling-up, policy

References
Public–private partnership to promote conservation agriculture: rice millers as an entry point to scale up innovation in rainfed lowland rice fields in Lao PDR

Patrice Autfray*¹,⁴, Ranjan Shrestha², Jean-Claude Legoupil¹, Lanlang Phanthanivong³, Khamkeo Panyasiri⁴

¹ CIRAD, UPR SIA, F-34398 Montpellier, France
² SNV, Lao PDR
³ PAFO Xieng-Khouang Province, Lao PDR
⁴ NAFRI, Lao PDR

*Corresponding author: autfray@cirad.fr

In Southern Lao PDR, as in other large areas of South-East Asia, small-scale farmers growing rainfed lowland rice face many sustainability challenges. The public sector and NGOs are developing different approaches to deal with these constraints, some of which are focused on market sector improvement (Gradl and Jenkins 2011) or on technical innovations based on the enhancement of land and labour productivity, such as conservation agriculture (CA) (Erenstein et al. 2012).

The objective of this abstract is to share the analyses of previous successful activities in southern Lao PDR in reaching the rice sector through rice mills (Shresta 2012) and in promoting integrated farming systems based on CA principles (Legoupil and Phanathivong 2012).

CA innovation and the value chain approach

Figure 1 shows how the rice value chain and products of diversification in lowland areas in Lao PDR have been integrated in the CA innovation process, giving access to lime amendments and synthetic fertiliser; high-quality seed in order to optimise fertiliser investment; specific mechanisation for rice direct-sowing in order to reduce labour and facilitate second-year cropping of grain legumes; fences to protect grain legume cropping against free cattle grazing after the rice harvest; and fences to protect forage crops in order to develop cut-and-carry–based forage and home cattle raising (Legoupil and Phanathivong 2012). During the 2-year project in six villages, paddy rice yields increased from 2.6 Mg ha⁻¹ in intensive agriculture to 3.7 Mg ha⁻¹ in CA, and labour needs dropped from 100 to 70 days ha⁻¹. Furthermore, introducing legume or cattle diversification generated record incomes thanks to market opportunities. A value chain program design could to be conducted to select service providers who could offer solutions to technical, financial and social issues. The provincial government could also play a role in facilitating the tax-free importing of fertiliser.
The inclusive business approach as a value chain intervention model

The inclusive business approach (Gradl and Jenkins 2011) pioneered by SNV (a Dutch aid agency) in Lao PDR (Shresta 2012) integrates low-income smallholders into small, medium and large business operations, creating sustainable livelihoods and increasing profitability. SNV and Helvetas (a Swiss aid agency) applied the approach in working with rice millers (Fig. 2).

The project has been able to develop fair trading relations between 21,361 smallholder rice-producing households and 21 rice mills during the project’s 23-month life. It proved a unique success thanks to the stimulation of cooperation between millers and farmers. Millers supported farmers with inputs, extension services and higher prices. In return, they received project support, funded by SNV, Helvetas and an EU grant, to improve their mills.

At the base of the project’s success lies a rigorous selection process to choose the most promising millers. Farmer’s crop yields increased by 30%, rice income increased by around 60%, and millers saw improved profitability in addition to a 10% increase in throughputs and a supply of high-quality, single-variety rice. Elements of the program are now spreading (including spontaneously), especially through miller groups.
Figure 2. The three milestones of a value chain intervention model generating increased incomes for rice farmers through direct investment in rice millers (after Shresta 2012).

Figure 3. Proposed public–private partnership operation model tying contract farming, business planning, input and extension supply, and product delivery.
How can the two approaches support each other?

In lowland areas in Lao PDR, there is much room to improve the rice sector at all stages from production to processing and marketing. Our analyses of previous activities support a new approach which combines technical innovation with market facility improvement based on public–private partnerships and the engagement of local traders. Rice millers provide high-quality inputs and extension services, at the same time improving postharvest processing and strengthening fair trade linkages. A public–private partnership operation model is given in Figure 3 as an example and could be used for other value chain products in Lao PDR and in other countries.

Keywords

Inclusive business, rice value chain, Laos

References


Portfolio 6 - Conditions for the adoption and extension of conservation agriculture

Conservation agriculture is now practised on more than 100 million hectares worldwide, including the United States, Brazil and Australia. However, most of that area involves large-scale mechanized farms located in the richest countries. Designing and extending no-till systems adapted to the specific constraints faced by small farming households in the South is a major rural development challenge for CIRAD, AFD and their national partners.

Several pilot projects sharing this goal are being conducted in very different contexts, from Southeast Asia (Cambodia, Indonesia, Laos, Thailand and Vietnam) to Africa (Madagascar, Cameroon) and South America. These projects have particularly highlighted a diversity of conditions for the adoption and dissemination of conservation agriculture. It is not possible to generalize those conditions to all agricultural and socio-economic situations. Many factors whose relative weight depends on specific contexts are involved, notably:

- The degree of environmental degradation: the more fields are degraded, the more farmers will feel the need to change their agricultural practices. Conversely, there is a threshold of environmental degradation beyond which it is not cost-effective to invest in fertility restoration;
- Access to land (level of saturation and ownership status of cultivated lands): when access to land is not a limiting factor, it is easier for farmers to adopt systems based on shifting cultivation;
- Competing uses of plant biomass, which is a key multifunctional stake: use for animal feed, common land practices, construction materials, etc.;
- Quality and duration of technical support when converting to conservation agriculture and DMC: long-term support, teaching skills of extension workers, capacities to adapt systems in real-time to local constraints and dynamics are key factors for adoption. Information and training of all stakeholders (farmers, extension workers, and policy makers) is also critical (401);
- Access to equipment, sometimes needed to overcome workforce availability problems for specific agricultural activities, such as land preparation or sowing (402);
- Access to plant material (403);
- Organization of agricultural production support services: short-term credit, provision of services for cropping activities (such as field preparation and sowing). Even when convinced by the potential economic and ecological benefits of conservation agriculture, many farmers may keep on with conventional farming due to a lack of such DMC services (need for critical mass and up-scaling).
401a – Laos
Field training in mechanization

H. Tran Quoc, Xayaburi, 03/2006

401b – Laos
Training in the use of hand-seeders

H. Tran Quoc, Xayaburi, 03/2006

401c – Laos
Field demonstration on the use of a manual boom-sprayer

H. Tran Quoc, Xayaburi, 03/2006

401d – Laos
Small-scale mechanization of spraying allows to reduce labor requirements

H. Tran Quoc, Xayaburi, 03/2006

401e – Vietnam
Field training in small-scale mechanization with extension workers

D. Hauswirth, Son La, 06/2012

401f – Vietnam
Field training in small-scale mechanization with extension workers

D. Hauswirth, Son La, 03/2006
402a - Laos
DMC seeder

H. Tran Quoc, Xayaburi, 04/2006

402b - Laos
Angle-roller to make mulch before sowing


403b et c – Laos
Collection of seeds of SEBOTA rice (high-yielding varieties under rainfed conditions)

H. Tran Quoc, Xayaburi, 09/2007

403a – Laos
Access to cover plant seeds is a key for extension

H. Tran Quoc, Xayaburi, 04/2006

403d – Laos
*Brachiaria ruzi* field

H. Tran Quoc, Xayaburi, 06/2011

P. Lienhard, Laos, 10/2011
Conclusion: a manifesto promoting rural policies accompanying the extension of conservation agriculture

There is a need for awareness today, in order to set in place the conditions required to extend an alternative agriculture enabling further intensification, while protecting a threatened environment.

This is becoming increasingly urgent as time goes by, if we wish to pass on to our children a natural heritage that has not been irreversibly damaged.
Chapter 7

Institutional viewpoints
Conservation agriculture production systems to improve rural livelihoods: the Sustainable Agriculture and Natural Resources Management Collaborative Research Support Program

Adrian Ares*1, Keith M. Moore1, and Michael J. Mulvaney1

1 Office of International Research, Education, and Development, Virginia Tech, 526 Prices Fork Road, Blacksburg, VA 24061, USA

*Corresponding author: aresa@vt.edu

Conservation agriculture (CA) production systems (CAPS) have been implemented on more than 100 million ha worldwide, especially in large-scale farming systems, but adoption by small rural households in disadvantaged regions of the world is still limited because of biophysical and socioeconomic reasons. Several programs have been initiated to overcome these limitations and foster the adoption of CAPS. Among them, the Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM CRSP) is sponsored by USAID’s Bureau of Food Security. SANREM CRSP collaborates with 7 US universities and 34 host country organisations in Bolivia, Cambodia, Ecuador, Ghana, Haiti, India, Kenya, Lesotho, Mali, Mozambique, Nepal, the Philippines and Uganda. The prime goal of SANREM CRSP is to increase smallholder food security through the development of participatory CAPS adapted to specific biophysical and societal conditions. Implementing CAPS requires minimising soil disturbance, maintaining year-round soil cover and using diverse plant species as much as possible. SANREM CRSP’s 7 lead projects and 4 cross-cutting projects generate new knowledge on different aspects of CAPS, promote farmers’ involvement and access to appropriate farm implements, train technical personnel, and develop microfinance mechanisms to help farmers move from intensive agriculture (IA) to resource-conserving practices. During the last year, SANREM CRSP trained more than 7000 farmers in 16 countries, generated 81 presentations and sponsored 56 undergraduate and graduate students (30 women) from 10 countries. Breakthrough research is being conducted in several areas related to the implementation and perception of CAPS, such as greenhouse gas emissions, incipient changes in soil organic carbon and social networks. Innovation is also promoted; for example, a multifunction implement that can be used as ripper, subsoiler and sweeper has been developed by researchers at the University of Wyoming and tested successfully in Kenya, Tanzania and Uganda. Some important research results relate to the increased resistance and resilience of CAPS to severe droughts, circumventing crop losses and the need for replanting that occurred under IA.
One successful SANREM CRSP project is carried out in close collaboration with PADAC (Projet d’appui au développement de l’agriculture du Cambodge) in Battambang, Cambodia, which has significant impacts in several critical areas:

1. Raising the involvement of collaborating farmers on 151 ha, in addition to other farmers who spontaneously tested CAPS on an additional 80 ha, in an area where no farmers practised CA at the beginning of the project in 2009.

2. Introducing, testing and promoting no-till planters and medium-sized sprayers that replace ploughing contractors and unsafe herbicide applicators. Some farmers have even pooled resources to buy machinery from Brazil to use on their farms, and will start to retail services to other farmers.

3. Training highly skilled technicians to help farmers in implementing CAPS.

4. Developing microfinance mechanisms to assist farmers in the transition from IA to CA.

At this time, there are excellent possibilities to scale up SANREM CRSP work on CA in Battambang, a priority area within the Feed the Future Initiative promoted by USAID in 20 countries, to reach thousands of farmers. To back up this effort, it would be critical to maintain widespread demonstrations, replicated field trials, seed production areas and germplasm collections (e.g. 263 rice and 57 soybean cultivars and 42 cover crops species and cultivars) established by PADAC in the Cambodian Ministry of Agriculture, Forestry and Fisheries in Bos Knohr, Kampong Cham.

The next challenge of SANREM CRSP is to scale up CAPS to end users through national agricultural research services, extension agencies, NGOs and private sector partners. Some limitations to the adoption of CAPS identified in SANREM CRSP projects are agronomic (limited experience with cover crops in high-elevation areas and on specific soil types; difficulties in achieving effective, economically feasible and safe control of competing vegetation); socioeconomic (strong competition for residues; unsecure land tenure; unavailability of microfinance mechanisms at reasonable interest rates to move from IA to CA; exposure of farmers to misleading information); technological (lack of appropriate farming implements for CAPS; limited knowledge of CA concepts and practical implementation); and institutional (reluctance of donor agencies to contribute funds to expand and continue CA projects).

Keywords
Resource conservation, technology transfer, education, SANREM CRSP
The role of conservation agriculture

In South-East Asia, as in most developing countries, agriculture still involves at least half of the population, and the rural population will remain high owing to the incapacity of cities to absorb the bulk of demographic increases. It also represents a large share of the economy in these countries, usually above 20% of the GNP. In addition, there is a stringent need to protect the natural capital, which is quickly degrading, to preserve soil and water (quality and quantity) and to limit greenhouse gas emissions, a quarter of which are generated by deforestation and intensive agriculture.

By allowing sustainable intensification of production, conservation agriculture (CA) may provide an answer to these concerns, because:

• it needs less space and is more intensive than traditional systems, and therefore can play an important role in reducing deforestation
• it does not have the detrimental effects on the environment of high-input agronomic models promoted by the Green Revolution (manufactured fertilisers, pesticides, mechanised tillage with high energy consumption)
• it has beneficial off-site effects (e.g. climate mitigation through carbon storage in the soil, reduction of water runoff and preservation of water quality).

Some specifics of CA

In its now prevailing accepted definition, CA is based on the 3 principles (http://www.fao.org/ag/ca/) of:

• continuous minimum soil disturbance (zero tillage)
• permanent organic soil cover (either living or dead)
• diversification of crop species grown in rotation or associations.

In contrast with ‘organic agriculture’, CA does not shun the use of modern inputs (pesticides, fertilisers, mechanisation), but the intensification it involves allows for a diminution of their use over time, natural improvements in soil fertility, biological control of pests and a reduction of energy consumption.
CA is knowledge intensive and should be thoroughly adapted to the natural and sociological conditions in each location by development teams with an in-depth knowledge of systemic research.

CA is a systemic type of innovation which departs from many technical innovations proposed in the last half century, mostly through the Green Revolution, which aimed at intensification through the use of modern inputs (chemicals and high-yielding cultivars) and mechanisation. The Green Revolution had a tremendous impact on yields; however, agricultural production and revenues seem to have reached a limit in both developed and developing countries: yields have reached a ceiling, and degraded soils require increased amounts of expensive fertilisers.

However, the promotion of large-scale CA faces several obstacles:
• Lack of expertise among technicians and extension officers, who are often unable to master the integrity of the concept.
• Unfamiliarity of academics and researchers, often highly specialised, with the systemic approach that is required.
• Difficulties for policy makers to support its promotion in the long term.
• Delays of several years to obtain tangible benefits.

Promotion of CA among small-scale farmers is a specific challenge because of limited education and difficulties in access to markets, modern inputs and equipment, in addition to a natural and understandable aversion to risk.

Role of ODA donors in the promotion of CA

As in the Green Revolution, official development assistance (ODA) institutions can be key pro-moters of CA, but their support has to be a long-term endeavour. Alone, they often do not have the capacity to finance the required applied research, training and extension support that are required for the large scaling up of these techniques and to alleviate the risk taken by farmers.

Different components of such support are required and should be carried out in parallel:
• Fundamental research (to understand in a scientific manner the processes involved)
• Action and development research
• Extension support
• Training on a large scale
• Incentives to farmers in the first years of implementation
• Advocacy.

Efforts should be carried out over the long term and could be discouraged by the slow path of progression of CA (especially among small farmers).
AFD experience

Agence Française de Développement (AFD) has given priority to the adaptation of CA techniques for small-scale farmers in developing countries. It started in the mid 1990s in Madagascar with the main objective of protecting the soils from the dramatic erosion there.

Working in close cooperation with CIRAD (see http://agroecologie.cirad.fr/), AFD promoted adaptive research (on-station and in farmers' fields) and supported extension to farmers (around 5000 ha of CA in various countries-see below).

Fifteen years ago, with the same approach and in cooperation with CIRAD, AFD promoted CA in PDR Lao (mostly Sayaboury province) to find an alternative to the devastating system of mechanised maize cultivation that was causing depletion and erosion.

The Lao experience was followed by developments in Vietnam (in partnership with NOMAFSI) and Cambodia, with the same approach of linking adaptive research and pilot extension for food crops (maize, cassava) and tree crops (rubber in Cambodia, tea in Vietnam). (See http://www.cansea.org.vn/)

Outside Asia, AFD has successfully promoted CA in rainfed medium-scale agriculture in Tunisia (20 000 ha) and Cameroon (10 000 ha), focusing on cotton–maize rotation systems in cooperation with the companies in charge of the cotton sector.

A total of around EUR 30m in grants has been invested in these actions.

The main lessons drawn from AFD’s experience can be summarised as follows:

• Medium- and large-scale agriculture should not be disregarded in CA promotion, because it has the capacity to invest, take risk and involve smallholders (through contractual arrangements).
• It is necessary to stabilise the test fields over a long enough time to show the full benefits.
• Even when CA promotion involves high policy levels (such as in Laos), ODA remains necessary to support the effort properly and to provide the required high level of technical assistance.

Suitable human resources able to promote fundamental research and action research in CA with the appropriate systemic approach are still limited and have to be strengthened.

Conclusion

In spite of difficulties encountered and the rather slow path of progress among small-scale farmers, CA is a strong concept, because it can respond to most of the challenges facing agriculture in the developing world: food security, agricultural intensification, environmental preservation, and climate adaptation and mitigation.

1 (See http://www.afd.fr/home/projets_afd/developpement_rural/Strategie_Dvpt_rural)
The ODA community has a key role to play in promotion of CA in both research and extension:

• ODA can provide the financial means to support the human resources necessary to adapt CA to the specific conditions of each country.
• It can provide the capacity of dialogue able to support local policymakers and convince them of the relevance of CA concepts over a sufficient period of time.
• It has the required longevity to accompany the slow process of CA diffusion.
• It can help provide the regional approach that is often required to strengthen national initiatives.

Keywords

Eco-intensification, systemic approach, ODA

Bibliography (available on AFD website)

AFD. Parole d’acteurs / Key players’ views • Gestion durable des forêts / Sustainable forest management • Lutte contre la désertification / Fight against desertification.
AFD. Histoire de projet / Project history • Développer les techniques d’agroécologie à Madagas-car / Develop agroecological techniques in Madagascar (film produced by AFD).
AFD. 2009. AFD and Rural Development.
CIRAD, AFD. 2011. Conservation agriculture and ecological intensification of small scale farms in the tropics: opportunities for partnership between research and development.
Conservation Agriculture With Trees, a form of Agroforestry - an institutional perspective

Meine van Noordwijk¹, Denis Garrity¹, Delia C. Catacutan*¹

¹World Agroforestry Centre (ICRAF)

*Corresponding author: D.C.Catacutan@cgiar.org

Historically agriculture in many parts of the world was compatible with the retention of valuable trees in cropped fields. It used only superficial soil tillage, usually in combination with a controlled fire that cleared the land but did not kill the larger trees¹. In temperate zones with relatively mild climates, however, a different approach to growing crops emerged, “non-conservation agriculture without trees”, which had success as it was readily scaled up with horse-drawn ploughs replacing human tillage, and tractors with ever-more horse power drawing ever-deeper ploughs through a soil that responded by mineralizing a substantial part of its organic matter, feeding the crops. This yield benefit, however, was not sustainable as it depleted the resource base – chemical fertilizer had to become the basis of plant nutrition. As tillage had killed many of the worms and other minute soil engineers, tillage became “necessary” to create a structure compatible with crop roots. The trouble started when this tree-less tillage-addicted form of agriculture became the norm, became known and taught worldwide as what agriculture is and should be, and was extended to parts of the world with less benign climates.

The term agro-forestry was coined in the mid 1970’s when the “green revolution” experience and debate had made clear that its perspective on intensifying crop production worked well in some (particularly irrigated) environments, but not elsewhere. A parallel approach to large-scale forestry had success in some limited areas, but it ran into major social conflicts and issues over land rights elsewhere.

The idea that crops and trees are not necessarily incompatible was revolutionary for academically trained agronomists, while trained foresters had a hard time in seeing local people as partners, not as their major problem. In many parts of the tropics, these perspectives appeared to be self-evident, if only one opens one’s eyes. Trees and crops, farmers and forest could typically work together.

¹An anecdote worth retelling is about a young British agronomist in charge of an integrated multi-donor Project Development Unit around 1980 in Southern Sudan, who asked and got permission from a Chief to carry out field experiments to compare new crop varieties with those locally used. When his team proceeded to clear the land of all trees a major conflict arose, and he was lectured by the Chief: permission to grow crops does not imply permission to remove trees… The agronomist later served on the Board of Trustees of the World Agroforestry Centre and recalled this as his initiation rite.
Yet, the advances in understanding the biophysical, ecological, social and economic aspects of tree-soil-crop interactions were slow to get mainstreamed in the world of “development” and “modernization”. New forms of agroforestry, compatible with mechanization and focussed on trees of high value finally emerged in Europe, North America and Australia – challenging the rules and and regulations that had been made on the concept of segregating trees and crops. “Conservation agriculture with trees” (CAWT) is a terminology that seeks to augment the conservation agriculture body of praxis and science, by (re)introducing trees. Yet, conservation agriculture is not without challenges. Replacing soil tillage by herbicide use as primary weed control strategy has its drawbacks – not the least of which is that tree roots if not regularly disturbed, can become too competitive for the crops. Cropped fields with trees can benefit from tree pruning and root pruning, a form of deep tillage adjacent to the trees.

**Conservation Agriculture with Trees is Now Making Headway on the Ground**

A key question in most CA systems is how to increase biomass production to enhance surface cover and generate more organic nutrients to bolster the long term sustainability of the systems. Recently, both the CA and agroforestry communities have mutually recognized the value of integrating fertilizer trees into CA to dramatically enhance both fodder production and soil fertility. Practical systems for intercropping fertilizer trees in maize farming have been developed and are being extended to hundreds of thousands of farmers in Southern and Western Africa. One particularly promising system is the integration of the leguminous tree Faidherbia albida into crop fields. This indigenous African acacia is widespread on millions of farmer’s fields throughout eastern, western, and southern Africa. It is highly compatible with food crops because it is dormant during the rainy season, while enhancing yields, improving soil health, and providing additional livestock fodder.

CAWT systems have demonstrated the ability to adapt crop productivity to climate variability and climate change, and provide greater yield buffering under increasing temperatures and more frequent and severe droughts. They should be attracting much more research and extension attention than has been the case so far. Depending upon which woody species are used, and how they are managed, their incorporation into crop fields and agricultural landscapes may contribute to:

- maintaining vegetative soil cover year-round
- bolstering nutrient supply through nitrogen fixation and nutrient cycling
- enhanced suppression of insect pests and weeds
- improved soil structure and water infiltration
- greater direct production of food, fuel, fiber and income from products produced by the intercropped trees
- enhanced carbon storage both above-ground and below-ground
- greater quantities of organic matter in soil surface residues
- more effective conservation of above- and below-ground biodiversity

---

2 Experiments with agroforestry in France in the 1990’s were deemed illegal, and major efforts were needed to change policies so that trees could be grown in cropped fields.
About half of all agricultural land in the world now has greater than 10% tree cover (Zomer et al 2009). In some regions tree cover on farm lands averages over 30%. In many countries the agroforestry area is steadily increasing.

Since the early 1990s, the World Agroforestry Centre and its partners in eastern and southern Africa have been developing a range of agroforestry systems that would improve soil quality and significantly boost crop yields, providing high returns on both land and labour.

The most popular system in southern Malawi, where land holdings are very small (<0.5 ha), is intercropping maize with nitrogen-fixing tree species of Gliricidia sepium, Sesbania sesban, Tephrosia species and pigeon peas. Sesbania sesban, Tephrosia (T. vogelli and T. candida) and pigeon peas are often relay-intercropped with maize. In these systems, farmers plant the trees in rows between their crops. Gliricidia is pruned back two or three times a year, and the leaves and the biomass are incorporated into the soil. Long-term experiments spanning more than a decade, involving the continuous cultivation of maize with Gliricidia in Malawi, have yielded more than 5 t/ha in good years, and an average of 3.7 t/ha overall, in the absence of mineral fertilizers. That compared with an average of 0.5–1.0 t/ha in control plots without Gliricidia or mineral fertilizer.

As the Zambian Conservation Farming Unit (CFU) worked to develop solutions to make conservation farming feasible for smallholders, they encountered the problem that more than two-thirds of their smallholder clientele couldn’t afford inorganic fertilizers, and have little or no access to manure or other nutrient sources. This fundamentally limited smallholder maize yields, and further depleted their soil fertility each year. To address the problem the Zambian CFU investigated the incorporation of Faidherbia albida trees into maize production systems. Their studies found that maize yields were typically 2.5 times higher in association with the trees. The effects tend to be most remarkable in conditions of low soil fertility.

The Zambian CFU now recommends that Faidherbia seedlings be planted in a grid pattern at 100 trees per ha. Fields with Faidherbia-maize CA systems managed with such a planting pattern (10 m x 10 m) accommodate mechanization. The result is a maize farming system under an agroforest of Faidherbia trees. The trees may live for 70-100 years, providing inter-generational benefits for a farm family, with a very modest initial investment. As the trees mature, and develop a spreading canopy, they are gradually thinned down to about 25-30 trees per hectare. Currently, the departments of agriculture in Zambia and in Malawi are encouraging farmers to establish Faidherbia trees in their maize fields, the aim being to increase food production sustainably. The efforts are backed by national policy and supported by the Zambia National Farmers Union.

The majority of farmers in Niger do not use the plow or the hoe for land preparation on their typically sandy soils. Rather, they use a hand tool used for loosening the soil and undercutting weeds that is passed just underneath the soil surface without inverting the soil.
They have also integrated agroforestry into a minimum tillage conservation farming system. The trees improve their crop yields, and the foliage and pods provide much-needed fodder for their cattle and goats during the long Sahelian dry season. Tree densities and tree cover in Niger have increased over time.

There are now about 4.8 million hectares of Faidherbia-dominated farm lands. These croplands also harbor tree populations of a wide range of other indigenous trees with up to 160 trees per hectare. Many villages now have 10–20 times more trees than 20 years ago.

**Current issues in agroforestry research**

International agricultural research under the umbrella of the CGIAR has four major goals (system level outcomes). It seeks to increase 1) rural income, 2) food security, 3) access to healthy food, while 4) achieving sustainable use of natural resources.

In that context, international agroforestry research has taken on three main challenges: 1) the need for more productive land use linked in with local, national and global value chains that improve rural income, 2) the need to maintain and restore land health as a basis of productive landscapes that provide the environmental services society expects (but so far poorly rewards) in addition to food production, and 3) the need to link knowledge and action in more effective ways, breaking out of “boxed-in” paradigms of how the world should be, and allowing greater influence for local voices, traditional ecological wisdom and knowledge, and integrated perspectives on sustainable development.

**A research agenda for Conservation Agriculture With Trees**

In supporting this form of agroforestry for dryland conditions, a multistep research agenda is emerging, which includes work on:

- Understanding the diversity of farm strategies, gender and equity: roles of livestock, farmer assisted natural regeneration, land access
- Tree - soil - crop interactions on farm, linked to input-output accounting
- Soil biota, infiltration and land health: time course of recovery
- Market integration of tree products: options in relation to transport costs
- Tree diversity, domestication and delivery: utilizing diversity for risk reduction, being prepared for climate shifts, meeting multiple needs and expectations; tree seed and seedling systems in delivery of “right trees for right places and good reasons”
- Buffering by trees of climatic and other variability
- Agroforestry policy initiative: reform of land access rights

There are many critical research issues to be explored with CAWT. These include the choice of appropriate tree species for varied agroecologies, higher quality tree germplasm, better tree seed dissemination systems, and further improvements in tree propagation and establishment methods.
The optimum tree densities for different CAWT systems have yet to be fully understood, and the best practices in exploiting the soil fertility synergies between organic and inorganic nutrient sources need to be elucidated. Integrated CAWT systems pose a pioneering research agenda with enormous implications for Climate Smart agriculture.

The World Agroforestry Centre is working on this agenda with a number of key partners from national research, universities and NGO’s in a number of projects across the developing world. It is part of broader ecological intensification efforts with CGIAR partners.
Glossary

3D  Three-dimensional
ACIAR  Australian Centre for International Agricultural Research
ADAM  Appui au développement de l’agroécologie en zone de montagne du Vietnam
(Support for Agroecology Extension in Mountainous Areas [of Vietnam])
ADB  Asian Development Bank
AFD  Agence française de développement
(French Agency for Development)
AusAID  Australian Agency for International Development
BDT  Bangladeshi taka
CA  conservation agriculture
CDKN  Climate and Development Knowledge Network
CIAT  Centro Internacional de Agricultura Tropical
(International Center for Tropical Agriculture)
CIMMYT  Centro Internacional de Mejoramiento de Maíz y Trigo
(International Center for the Improvement of Maize and Wheat)
CIRAD  Centre de coopération internationale en recherche agronomique pour le développement
(Centre for International Cooperation in Agronomic Research for Development)
CNRS  Centre national de la recherche scientifique
(National Centre for Scientific Research)
FAO  Food and Agriculture Organization of the United Nations
FFS  farmer field school
GIS  geographic information system
GPS  Global Positioning System
IA  intensive agriculture (= conventional agriculture)
ICARDA  International Center for Agricultural Research in the Dry Areas
ICRAF  World Agroforestry Centre (formerly International Centre for Research in Agroforestry)
IPDM  integrated pest and disease management
IPM  integrated pest management
Feeding an increasing number of people through sustainable intensive agriculture has recently become one of the most important challenges humanity has ever faced. Within a global context of rising uncertainty and gaps between production and other ecosystem services, achieving this objective requires major efforts to develop innovative and adequate green production practices.

At the moment, it is estimated that out of 1.3 billion people whose livelihoods directly depend on agriculture, only 30 million own a tractor and only 300 million have animal traction. One billion people face hunger. When reading these numbers, everybody can easily understand how vital it is to support small-scale family farmers who have to battle hard with very few resources in order to adapt to local and global changes.

With its partners worldwide, CIRAD has been involved for more than 20 years in designing and assessing agricultural solutions for the most vulnerable people, aiming to intensify production and, at the same time, protect nature and biodiversity. Sustainable agricultural intensification is one of the structural pillars of CIRAD’s field of research for development. Through this approach, agroecology and conservation agriculture have been found to have potential for rural development and have taken on more and more importance over time, with a growing number of scientists engaged in various research situations.

It is obvious that the task is not an easy one. Further research and development are needed to design and propose relevant options in highly diverse contexts. Synergic actions with farmers and research stakeholders from all regions of the world are required to shape the next stage of agriculture.

Meanwhile, the work compiled in this book proves that the aim of sustainable agriculture is largely shared by the research for development communities. It also provides evidence of being on the right track to reverse the trends and allows us to hope that production needs can be met while saving natural resources for the benefit of our children.

Dr. Gérard Matheron
President Managing Director of CIRAD
The 3rd International Conference on Conservation Agriculture in Southeast Asia

Hanoi · 10th > 15th December 2012

www.conservation-agriculture2012.org