Chapter 8
Leapfrogging Agricultural Development: Cooperative Initiatives Among Cambodian Small Farmers to Handle Sustainability Constraints

Arnim Scheidel, Bunchhorn Lim, Kimchhin Sok and Piseth Duk

Abstract Many small farmers across Cambodia are currently facing multidimensional sustainability challenges, such as the need to produce sufficient food for home consumption and income generation, while keeping pressures on land, labour and the environment at bay. This chapter illustrates these challenges through the socio-metabolic analysis of a non-industrialized rice farming village in Kampot Province. Apart from these challenges, the chapter also describes how some villagers have adopted a series of 'low-capital' and cooperative innovations and initiatives to handle some of these issues. At the same time, they have partly bypassed more conventional pathways such as green revolution techniques and the transition to fossil LP gas fuels. The adopted initiatives include agroecological techniques such as the System of Rice Intensification (SRI), to increase yields while reducing farming inputs; a small-scale biogas system for cooking and lighting; a community bank to address villagers' financial needs; a community-operated paddy rice bank to manage transitory food shortages; and a rice mill association to increase farmers' market performance. These developments can enhance the sustainability of resource use patterns, understood to be strongly embedded in local socio-economic dynamics. Diffusion of such cooperative, knowledge-based initiatives in the small-scale farming economy therefore bears the potential to leapfrog more conventional

A. Scheidel (✉)
International Institute of Social Studies (ISS), Erasmus University Rotterdam (EUR),
Kortenaerkade 12, 2518 AX The Hague, The Netherlands
e-mail: arnim.scheidel@gmail.com; scheidel@iss.nl

B. Lim
Department of Commerce, Kampong Thom Province, Cambodia
e-mail: limbunchhorn@gmail.com

K. Sok · P. Duk
Ecosystem Services and Land Use Research Centre (ECOLAND),
Royal University of Agriculture (RUA), Phnom Penh, Cambodia
e-mail: sokkimchhin@gmail.com; sokkimchhin@rua.edu.kh

P. Duk
e-mail: duk.piseth@gmail.com

E. Fraňková et al. (eds.), *Socio-metabolic Perspectives on the Sustainability of Local Food Systems*, Human-Environment Interactions 7,
https://doi.org/10.1007/978-3-319-69236-4_8

agricultural development pathways. Simultaneously, they can foment the creation of local agroecological knowledge, cascading resource uses and the closing of nutrient cycles, as well as economic democratization and a fairer participation of farmers in the food trade chain. Cooperative agricultural development may thus be vital for local sustainable food systems.

Keywords Cooperative economy · Leapfrogging · System of rice intensification · Community finance · Biogas digester · Paddy rice bank · Cambodia

8.1 Introduction

Cambodia's small-scale farming sector is a central pillar of the largely rural economy. It not only represents a source of livelihoods for around 75% of the population, but is also central to food security, contributing with agricultural production to both subsistence household consumption and to the increasing demands of a growing urban population (NIS 2010). As agents that actively shape land use patterns, which are at the core of many environmental challenges (Erb 2012), small farmers play a crucial role for sustainability, not only in Cambodia, but also globally, where they account for the vast majority of farms today (Mayer et al. 2015; Fraňková et al., Chap. 1 in this volume).

Yet, nowadays many small farmers across Cambodia face multidimensional challenges in creating and maintaining sustainable rural livelihoods. Hit by a wave of land grabbing, the availability of agricultural land for small farmers and access to forests that have traditionally supplied them with important livelihood resources, has rapidly declined on the country level (Scheidel et al. 2013; Jiao et al. 2015; Scurrah and Hirsch 2015). In spite of small land entitlements, local farming systems are nevertheless required to produce sufficient food for household consumption as well as enough agricultural goods for the market for income generation. While commonly taken development paths, such as green revolution techniques or rural-urban migration to increase incomes through non-farm work, offer some solutions to the challenges of land shortage, they can also produce new problems across other dimensions. For example, an increasing use of fertilizers would enable the boosting of paddy rice yields, which are below the Southeast Asian average. However, it also comes with increasing expenditure on agricultural inputs, which many smallholder in Cambodia cannot afford (Theng et al. 2014). Moreover, increases in well-known environmental pressures on soils and water bodies follow (Tilman 1999), as well as rising greenhouse gas (GHG) emissions through fertilizer production and application (Snyder et al. 2009). Such 'simple' solutions in one dimension may thus directly produce new challenges across other sustainability dimensions (Giampietro 2003).

This chapter aims to illustrate and discuss these challenges, based on a socio-metabolic analysis of a non-industrialized rice farming village in Kampot province, Cambodia. Apart from addressing the challenges faced, we also present a series of innovative alternative developments, adopted by villagers to deal with a series of sustainability issues. Fundamental to the sustainability question is whether alternative pathways exist that would allow for leapfrogging, i.e. bypassing of the well-known environmental and social problems of conventional development pathways. Within this context, the adequate diffusion of cleaner production technologies has received much attention (Perkins 2003). In this chapter, we illustrate that not only technological, but also institutional and organizational, changes can support leapfrogging, particularly through the diffusion of knowledge- and cooperative-based resource management models and practices. Such changes may enhance sustainable resource use patterns, for example through enabling local nutrient cycling, or the creation of place-based agroecological knowledge. Furthermore, they can also facilitate democratic control over resources as well as supporting fairer participation in food trade chains (Tello and González de Molina, Chap. 2 in this volume).

After providing background information on Cambodia and the farming village presently discussed (Sects. 8.2 and 8.3), a detailed analysis of multidimensional challenges through the lens of societal metabolism follows (Sect. 8.4). The chapter then goes on (Sect. 8.5) to specifically discuss how some of the challenges are addressed through innovative alternative developments: (i) agroecological techniques (System of Rice Intensification) to increase yields while reducing water, seeds and fertilizer needs; (ii) small-scale biogas systems to make cascading use of manure and to reduce firewood demand for cooking; (iii) a community bank to address villagers' financial needs to adopt new assets; (iv) a paddy rice bank to manage transitory food shortages; and (v) a rice mill association to increase small farmers' market performance while retaining valuable by-products. We close the chapter (Sect. 8.6) by arguing that resource use patterns are strongly embedded within socio-economic dynamics. Many of the presently described alternative developments therefore bear the important potential to enhance the livelihoods and the sustainability of resource use patterns of land constrained farmers through the diffusion of low-capital, cooperative and knowledge-based agricultural models and practices.

8.2 The Rural Economy of Cambodia

Cambodia is largely a rural economy, with paddy rice being the most important staple food and agricultural product. Although rice production is largely dedicated for household consumption and local market supply, the country has steadily increased surplus production for export. The rice distribution system has developed quickly since 1996; the first year after the civil war that a stable rice production surplus was achieved. While Cambodia is still a small player in the world rice market, even compared to neighbouring countries like Laos, Vietnam and Thailand, production and trade has been constantly growing (ADB 2012). During 2013, Cambodia produced 9.4 million tons of paddy rice, of which it exported 361,246 tons of milled rice, with a value of around $260 million (FAO 2015). Much of the rice production is based on small-scale farming, whereas currently 70% of the 3.3 million ha of household agricultural holdings are dedicated to rice crops (NIS 2015).

Cambodia's small-farmer sector has experienced turbulent transformations during the last decades, which have imposed profound changes and challenges on small farmers. During the rule of the Khmer Rouge (1975–1979), private ownership of land was abolished and large parts of urban as well as rural populations were uprooted and forced to collectively cultivate fields in those areas most suitable for rice production, i.e. mostly in Northern and Central Cambodia. It was estimated that up to 2.8 million people lost their lives during the Pol Pot regime (Heuveline 1998). This radical agrarian collectivization came to an end under the subsequent Vietnamese occupation and the People's Republic of Kampuchea (PRK) (1979–1989). Many farmers then returned to their original villages in search of their families and farming lands. Subsequently, 'solidarity groups' (*krom samakhi*) were established by the PRK, comprising of 10–15 families, which were recognized as central units of rural development. In 1989, private property was reintroduced under the transitional State of Cambodia (1989–1993), followed by processes of land registration and titling, and the family farm as the main unit of agricultural production increasingly returned. After the 1993 transition, in which Cambodia turned into a constitutional monarchy operated as market-oriented democracy, inequality in landholdings through land concentration increased notably. The government further started to set up a concession economy in order to develop the rural sector. In particular, since the turn of the millennium, vast tracks of rural areas have been transformed due to the granting of Economic Land Concessions (ELCs) for agro-industrial development (for details see Chandler 2008; Diepart 2015).

Within the scope of this chapter, we are unable to provide a detailed account of all the implications these changes have had for the current rural sector. Yet it is relevant to point out that this recent and tumultuous history of rural Cambodia has much contributed to the current situation of lack of agricultural infrastructure and weak land governance (Diepart 2015; Grimsditch and Schoenberger 2015; Scurrah and Hirsch 2015). Moreover, Cambodia has experienced a rapidly growing rural labour force. This is partly due to the Khmer Rouge genocide, which massively diminished population cohorts of people aged above 35–40 (that is, born before the genocide). In turn, cohorts below that age have also grown rapidly due to a post-war baby boom (Diepart 2015). Consequently, rural areas are increasingly unable to absorb the growing rural labour force based on family farming; this is also because more than 2 million hectares of available land has been granted as ELCs to domestic and international agro-business developers (Licadho 2015). This has not only caused a massive land grab crisis, in which more than 700,000 people have so far been adversely affected—by such land deals, through overlapping land concessions and loss of forest livelihood resources—but also that land is becoming an increasingly scarce resource at the country level (Leuprecht 2004; Licadho 2009; CCHR 2013; Scheidel 2016). ELCs are thus posing limits to expansion of smallholder agriculture on the country level and consequently, many Cambodian small farmers, including the villagers of the case study introduced below, find themselves in need of making a living based on very small land entitlements. Intensification strategies are becoming prominent options to increase production, as well as out-migration, which increases incomes from other livelihood activities. The vulnerability of farmers, already making a precarious living, may increase further with the effects of climate change—changes in precipitation patterns, floods and droughts. Cambodia is in fact among the countries most vulnerable to climate change (Yusuf and Francisco 2009).

In this chapter, we share the challenges of land constrained small farmers, as well as the creative ways to deal with them, by reporting from a village (of which the name is kept anonymous) located in Kampot Province. In Kampot, only a few ELCs were granted, yet it is among the more densely-populated regions in Cambodia, where demographic changes also play out. Most family farms depend on non-industrialized wet season rice farming, and access to common pool forest resources is limited. The whole commune in which the village is located had only 2 ha of forest land during the time of field research (2011). Yet it is comprised of five villages and has a total population of 3954 villagers.[1] Basic infrastructure, such as roads and wired electricity, were generally not developed much in the region (NCDD 2009). While on average Cambodian farming households hold 1.6 ha of agricultural land (excluding homelot), with 47% of them having less than 1 ha, in Kampot Province average holdings are at 1.03 ha/household, with 59% below 1 ha (NIS 2015). In the studied village, almost 70% of all households own less than 1 ha, and average land holdings are down at 0.91 ha/hh (own survey data). The studied village is thus an illustrative example from which to learn how smallholders have been able to deal with little and limited access to land (Scheidel et al. 2014).

8.3 Concepts, Methods, Data Sources

8.3.1 Concepts and Methods

The methods employed in this chapter draw from the concept of societal metabolism and the related MuSIASEM approach (Multi-scale integrated analysis of societal and ecosystem metabolism) (Giampietro and Mayumi 2000a, b; Giampietro et al. 2009). The concept of societal/social metabolism focusses generally on the appropriation, transformation and disposal of materials and energy by a given society in order to create and reproduce itself. MuSIASEM offers an accounting framework that allows structuring a quantitative analysis of how selected flows (e.g., biophysical flows, monetary flows) are produced, traded and consumed by certain structural elements of a socio-economic system, such as through land uses,

[1]The administrative units in Cambodia are structured as follows: village, commune, district, province, country.

and people and their activities. Following the conceptual framework of Georgescu-Roegen (1971), these structural elements, which need to be maintained and which provide important transformative services within the economic process at a given rate, are termed *funds*. MuSIASEM is an 'open grammar' instead of a closed and standardized accounting framework, which means that the analyzed flows and funds need to be initially defined according to the research focus (see Tello and González de Molina, Chap. 2, of this volume for a discussion of different socio-metabolic approaches).

For the analysis of rural systems, MuSIASEM applications have commonly focussed on the production and consumption of biophysical and monetary flows through the funds 'land use' and 'human activity' (Gomiero and Giampietro 2001; Giampietro 2003; Ravera et al. 2014; Serrano-Tovar and Giampietro 2014). This chapter follows this approach; however, we note that there are also other funds worth analyzing, such as machinery or livestock, which we discuss here only in general terms (see for example Chap. 5 by Padró et al. of this volume, for a detailed analysis of the role of the livestock fund). Land use is commonly subdivided into categories of non-colonized land (i.e., largely natural forests, rivers) and colonized land (agriculture and livestock land, buildings and roads). Categories of human activity, although often overlapping, can be divided into physiologically relevant activities (sleeping, eating and personal hygiene), socially relevant activities (education, leisure time, and local cooperation activities), and productive activities (household work including family care work, farm and livestock work and other productive activities). Note that various options exist for grouping activities into meaningful categories. For example, the activities that are here, and generally within MuSIASEM, grouped under the categories of Physiological Overhead (i.e., sleeping, eating and personal hygiene) and Social Overhead (i.e., education, leisure time, meeting friends and community members), have been grouped by Singh et al. (2010) under the category Person System. This needs to be taken into account when comparing different time use studies of rural systems.

While both land uses and human activity (i.e. labour time) act as crucial livelihood resources, they are also constraints as their availability is limited and they need to be maintained and reproduced (Pastore et al. 1999; Grünbühel and Schandl 2005). In addition to the common focus on land and labour dynamics within agrarian studies, MuSIASEM and other time use studies allow us to widen the perspective by focussing not only on *productive* land and labour, but also on the *non-productive* and *reproductive* uses and how they are intrinsically related to each other. In this chapter, we quantify allocation of land use and human activity across the above-mentioned categories in order to understand the role they play as both producing and consuming elements of the local food system. The scale of analysis is the village economy. With regard to the studied monetary flows, we reconstructed all income and expenditure flows across defined categories, based on a randomized household survey (see Sect. 8.3.2 Data Sources). With regard to biophysical flows, we did not aim to address all possible flows but rather those that were most important to understanding the functioning of the local food system and its direct interaction with the local environment from a rural livelihoods perspective, i.e. production of agricultural goods, consumption of farming inputs, and estimation of firewood needs for cooking. Units were left as reported (e.g., kg of paddy rice production, litres of gasoline use, etc.) as they represent meaningful units in understanding the village economy and related challenges from a farmers' perspective.

In order to address the sustainability issues of local food systems, it is crucial to look at biophysical and environmental dimensions in direct relation to socio-economic dimensions; hence to employ a nexus perspective. To arrive at such a multidimensional reading of the farming system, graphical representations commonly used in rural MuSIASEM are employed here. Figure 8.1 will show the allocation of flows and funds within the village economy, following the scheme developed by Serrano-Tovar and Giampietro (2014) and Scheidel et al. (2014). While this enables a good graphical representation of the village economy in terms of land use, time use, and related production and consumption activities, Table 8.1 further provides a series of related numeric indicators. Finally, MuSIASEM's Impredicative Loop Analysis (ILA) has been adapted for a nexus analysis to illustrate how the 'simple' conventional solution of closing the yield gap through agricultural intensification in fact turns into a multidimensional challenge. An ILA typically quantifies the interactions between several flow/fund elements that belong to different scales of the systems, hence showing the forced quantitative relations between the whole and parts of the whole (Giampietro 2003). However, this chapter employs the same type of graphical visualization in a looser way, with its main purpose being to show the forced linkages between different flow and fund elements. The visualization shown in Fig. 8.2 consists of four axes where each axis represents a different flow/fund element: total agricultural land, total paddy rice production, fertilizer inputs, and selected monetary flows. The forced relationship between these extensive values becomes visible at their interface, i.e. through the generated intensive variables, such as for example yield (kg/ha), or pressures from agro-chemicals (kg/ha). Hence, this type of graph is used here to illustrate the linkages between environmental and socio-economic dimensions.

8.3.2 Data Sources

Data employed are mainly primary data, collected by the authors between March and May 2011 with the help of three enumerators. Primary data collection methods included a random household survey to collect information on demography, livelihood activities, land uses, income and expenditure, time use and local cooperation activities at the household (hh) level. The total random sample covered 86 out of 195 hh, which is a representative sample at the village level with a confidence level of 8%, assuming normal distribution of selected characteristics across the surveyed population. Cambodian Riels were converted to US dollars, based on the exchange rate of \$1 = 4100 Riels, which was a common exchange rate in the village and nearby towns at the end of 2010 and beginning of 2011. Detailed survey design and data processing methods are reported elsewhere (Scheidel 2013).

Furthermore, 19 semi-structured interviews were conducted with key informants, including both local government officials, and representatives from grassroots cooperation groups, who explained and shared data on the new alternative developments discussed in this chapter. Participant observation was crucial to understand, validate and contextualize the collected information of the survey as well as the interviews. While survey data are limited to the agricultural year 2010–2011, the new initiatives adopted by the villagers were tracked through phone interviews until May 2016. These interviews focused mainly on the questions of how they have developed since 2011.

Firewood demand for cooking was estimated for the share of households (95%) that reported to fully depend on firewood as cooking fuel. During field research, no single household used LP gas or wired electricity as a cooking source. The remaining 5% mainly used the new small-scale biogas system as cooking fuel (Sect. 8.5.2). Average firewood consumption values for rural Cambodia were kindly provided by GERES,[2] who report between 32 and 40 kg of firewood/hh/week, depending on the cooking stove design (personal communication). Based on the more conservative value of 32 kg/week, an average monthly firewood demand of 139 kg/hh was estimated. This is in line with another study from a similarly resource-constrained area in Svay Rieng province (UNDP 2008), in which households consumed around 145 kg of collected firewood per month. No data could be estimated for the use of palm fronds and animal dung as a cooking source, however, they are assumed to play a role as cooking fuel in times of fuelwood shortages. No information was available for the use of cooking fuelwood for other purposes, such as palm sugar production. Hence, estimated fuelwood demand represents a conservative approximation. Humanure was roughly approximated using average data from agricultural villages on dry matter/capita/day from Gotaas (1956). Animal manure data could not be estimated due to a lack of data regarding livestock composition.

8.4 The Village Economy from a Socio-metabolic Perspective

8.4.1 Sustainability Chances and Challenges

We now turn to a discussion of several sustainability challenges of the small farmer village from a socio-metabolic perspective. Figure 8.1 shows the village metabolism during the agricultural year 2010/2011 in terms of their funds (land use and human activity) and the associated production and consumption of biophysical and monetary flows. Note that these values represent aggregated average values for the village economy, whereas differences exist at the household level in terms of

[2]The Group for the Environment, Renewable Energy and Solidarity (GERES) is a non-governmental organization, specialized in the promotion of sustainable and renewable energy use. It has a strong presence in Cambodia and Southeast Asia. http://gsea.regions.geres.eu/.

household demography, distribution of productive assets and incomes. For instance, the top quintile holds 33% of agricultural land, while the lowest quintile holds only 7% of all agricultural land. While the implications of such differences are relevant to understand individual household livelihood strategies (Scheidel et al. 2014; Scheidel and Farrell 2015), in this chapter we focus centrally, on the sustainability challenges of the village economy as a whole.

Broad categories of human activity are represented on the left side of Fig. 8.1. 58% of the annual time budget is spent on activities relevant for physiological well-being, such as sleeping, eating and personal hygiene. 22% of the annual time budget is spent on activities with social relevance, particularly education (4%), meeting friends or fellow villagers, and leisure (18%). 20% of time is spend on productive activities, including household chores, farm work and non-farm work. Land use types are represented on the figure's right side. According to the village chief and survey data, the total village area amounts to 195 ha, of which 170 ha (87%) is agricultural land and 21 ha is residential land (11%). The remaining 2% is comprised of river canals, meadows and roads. Around 11 ha of land from outside the village has been rented by villagers for further paddy rice production, increasing access to agricultural land to about 181 ha.[3] Total amount of livestock, relevant for food production, income generation and agricultural labour were estimated to amount to 435 cattle, 211 pigs, 14 buffalos, and 5000 hens and ducks.[4] Livestock, particularly cattle, is fed in the dry season through grazing on villagers' agricultural land. In the wet season, when open grazing spaces fall short, agricultural by-products, i.e. rice straw from previous yields, play an important role as livestock fodder, which is maintained in good quality throughout the year thanks to traditional storage techniques.

The produced, traded and consumed flows that leave and enter the village are represented at the top and the bottom of Fig. 8.1, while those that stay within the village are represented in the area termed 'village system'. No data were available on the amount of money, time and physical assistance (i.e. paddy rice stocks) that entered the village through NGOs and governmental programmes. Nevertheless, Fig. 8.1 indicates them as relevant flows of our analysis, as they have had an important influence on how the village has developed (see Sect. 8.5). The figure shows that at the village level, gross revenues and expenditure flows are roughly able to cover each other; however there are no savings at all (red arrows). Further, much of the produced food (i.e. paddy rice) is used for household consumption, whereas livestock production plays a crucial role for sale and income generation (green arrows). Also, the allocation of productive activities remains largely within the village, and only a smaller share of them leaves the village for non-farm work (blue arrows). A detailed numerical characterization through indicators derived from this socio-metabolic analysis can be found in Table 8.1.

---

[3]No information on land rented out to neighbouring villagers was found and according to interviews it did not play an important role.

[4]No information on livestock composition was available that would allow the calculation of LU500 units.

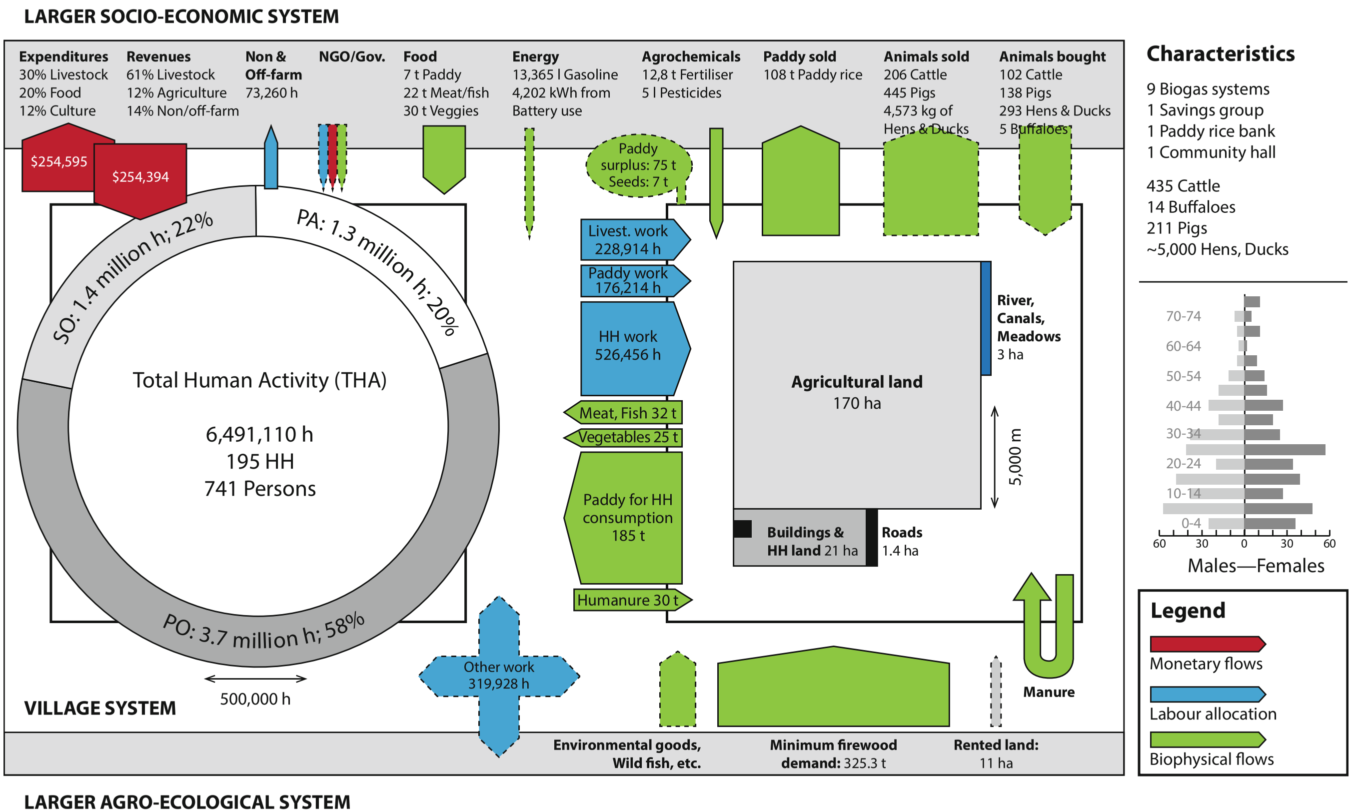

Fig. 8.1 The societal metabolism of the rice farming village. Own elaboration based on survey data, adapted from Scheidel et al. (2014). *Note* THA = Total Human Activity; HH = Household; PO = Physiological Overhead; SO = Social Overhead; PA = Productive Activities; t = tons; l = litres. For a detailed description of how time use accounts were calculated, see Scheidel (2013). Arrows represent labour allocation, biophysical and monetary flows. They are generally scaled, but where no data have been available, they are represented in dashed lines

Table 8.1 Multidimensional food system performance indicators, derived from the MuSIASEM analysis at the village level

Relevance	Description	Performance indicator	Value	Unit	(First value)	(Second value)
Economic	Gross revenues rice farming (land use)	Gross monetary returns per land area[c]	510.60	$/ha	27,158	53.2
	Gross revenues rice farming (time use)	Gross monetary returns per hour of activity[c]	0.52	$/h	27,158	52,715
	Gross revenues livestock (land use)	Monetary returns per land area	799.76	$/ha	155,115	194
	Gross revenues livestock (time use)	Monetary returns per hour of activity	0.68	$/h	155,115	228,944
	Gross revenues off-farm work	Monetary returns per hour of activity	0.25	$/h	3363	13,665
	Gross revenues non-farm work	Monetary returns per hour activity	0.56	$/h	33,126	59,595
	Labour dependence on external labour market	Share of labour hours allocated outside the village	4%	% (h/h)	59,595	1,327,830
	Financial dependence on external incomes[b]	Share of gross income from work outside village	17%	% ($/$)	43,567	254,394
	Expenditure farming agro-inputs (fert./pest.)	Costs per land area[a]	44.26	$/ha	8003	181
	Expenditure farming non-family labour	Costs per land area[a]	21.17	$/ha	3828	181
	Expenditure livestock maintenance	Costs per land area[a]	37.79	$/ha	6834	181
	Expenditure livestock buying new animals	Costs per land area[a]	392.09	$/ha	70,898	181

(continued)

Table 8.1 (continued)

Relevance	Description	Performance indicator	Value	Unit	(First value)	(Second value)
Agronomic	Average land holdings	Total agricultural land owned per household	0.91	ha/hh	176.64	195
	Food sovereignty (total production)	Self-sufficiency in years of consumption covered by total annual production	1.96	Years	375	192
	Food sovereignty (after market sale)	Self-sufficiency in years, after selling paddy rice	1.39	Years	267	192
	Paddy rice yields per agricultural land[a]	Paddy rice production per land area	2076	kg/ha	375,000	180.8
	Paddy rice yields per labour time invested	Paddy rice production per hour	2.1	kg/h	375,000	179,214
Social	Time use with physiological relevance	Share of sleeping, eating, personal hygiene out of THA	58%	% (h/h)	3,766,577	6,491,160
	Time use for social activities	Share of education and leisure out of THA	22%	% (h/h)	1,396,781	6,491,160
	Upon which formal community meetings	Share of formal community meetings out of social activities	0.6%	% (h/h)	7905	1,396,781
Ecological	Fertilizer use	Amount of fertilizer per land area[a]	70.67	kg/ha	12,778	181
	Pesticide use	Amount of pesticides per land area[a]	0.03	l/ha	5	181
	Demographic pressure	Persons per ha of agricultural land	4.37	Persons/ha	741	169.73
	Land use pressure	Colonized land per total village land (%)	98%	% (ha/ha)	192.39	195.39
	Fossil energy use (gasoline) per HH	Gasoline consumption	68.54	l/hh/year	13,365.44	195
			21.55	KwH/hh/year	4202	195

(continued)

Table 8.1 (continued)

Relevance	Description	Performance indicator	Value	Unit	(First value)	(Second value)
	Electricity use per HH	KwH/hh from battery use				
	Cooking fuel wood needs	Annual cooking fuelwood demand (low estimate)	1669	Kg/hh/year	325,372	195

Note Dimensions of relevance are only separated for structuring purposes, yet in practice they overlap largely. [First value] and [second value] are presented to indicate the absolute numbers, on which basis the relative indicators were constructed. [a]Includes rented agricultural land; [b]includes remittances, pensions, non-farm work. [c]Gross monetary returns on rice farming were calculated by accounting only for the share of land and labour inputs required for the share of rice sold on the market (29%). *Source* own survey data

From a sustainability perspective, the village shows positive performances in some aspects as well as large challenges in other dimensions (Table 8.1). Among the positive social aspects is that villagers are 'rich in time', meaning that in comparison with other (agrarian) societies, they have a comparatively large share of time allocated to the physiological overhead, as well as a large share dedicated to social and leisure activities [compare e.g. with Grünbühel and Schandl (2005) for neighbouring Laos; and NIS (2007) for average Cambodia]. This, it can be argued, allows social well-being and resilience, as people have time for cultural and social activities. Villagers have also been able to build up a strong network of cooperation, which is largely maintained by only a small share of social activities (0.6%) dedicated to formal community meetings and activities (Scheidel and Farrell 2015). Finally, the strong allocation of productive activities within the village economy itself also enables flexible family care, as many activities can be combined (e.g. household work and provision of elderly or children). Increasing out-migration can challenge such flexible arrangements based on proximity.

From a food systems perspective, the village economy is highly localized and able to be completely self-sufficient in terms of paddy rice, meat and vegetable production. Hence food sovereignty is assured at the village level from a *production* perspective, although *distribution* issues also matter. Distribution is currently achieved through trade on local markets: while some villagers sell their vegetable and meat surplus, others buy it from the market. Finally, from an environmental perspective, positive aspects include the absence of pesticide use (on average, only 0.03 l/ha), as well as the low consumption of fossil energy. Gasoline use amounted on average to about 69 litres per household, and electricity consumption through use of car batteries was on average less than 22 kWh/hh/year. During the time of field research, no single household accessed wired electricity; hence sources were limited to batteries, which were recharged in neighbouring villages using diesel generators.

With regard to livelihood challenges, we can see that access to the main productive asset 'land' is quite low, with average agricultural holdings of 0.9 ha/hh, and also well under the low national average of 1.6 ha/hh (NIS 2015). Further, demographic pressure in 2011 was at 4.4 persons/ha, while population dynamics mirror the countrywide dynamics (see population pyramid, Fig. 8.1). The village has a young population with a growing labour force, whereas more young people are entering the economy than elderly people retiring. This drives the need for either further land for small farming, or non-farm jobs to enter other economic sectors. Yet the village has reached already its biophysical limits of agricultural expansion: 98% of all village land is already colonized land, i.e. under residential, agricultural, or infrastructure use (Table 8.1). Hence, rather than an expansion of agriculture, either intensification, or changes in livelihood strategies will be required to overcome biophysical limits of the current village economy. With average paddy rice yields at around 2.1 t/ha, there is technically space to increase yields through green revolution techniques to the national average of 2.9 tons/ha (MAFF 2014). However this also comes with trade-offs discussed later (Sect. 8.4.2).

Regarding economic challenges, Fig. 8.1 shows that the village economy is hardly able to cover its own expenditure without an annual deficit. In fact, agriculture only contributes about 12% to the gross monetary revenues. Table 8.1 shows that rice farming has on average a monetary return of 510.60$/ha and 0.52$ per labour hour; however, only 29% of produced rice is for market sale, while the remaining stays in the village for subsistence and food security purposes. Livestock production in turn accounts for 61% of gross incomes, with a gross revenue rate of around 800$/ha and 0.68$/h of time investment, but it also requires initial capital to invest in livestock that can be sold later on, when fully grown. Currently, the village economy is unable to meet expenditures solely through working in agriculture and livestock production. Non-farm work, usually involving seasonal migration to the new industries (garment sector, construction work, etc.), has a medium average return of 0.56$/h. Yet it depends on seasonal availability and, further, may provoke social challenges through out-migration, disrupting family life. At the time of field research, the external labour market absorbed only 4% of all productive activities, which, however, contributed to 17% of gross monetary revenues (including remittances and pensions).

Finally, there are also environmental challenges. In 2008, all households depended on firewood as cooking fuel (NIS 2008) and in 2011 only 10% of all households had adopted new sources by making use of biogas produced through animal and humanure. Conservative estimates indicate a total firewood demand of at least 325 tons per year (Fig. 8.1), but the lack of access to forests makes local firewood supply problematic. All households collect firewood and other cooking fuels, such as palm fronds from their own homelots and the few meadows available. Households further reported purchasing firewood from external traders or collecting it themselves from remote forests. Being constrained in local supply, it can be assumed that other fuel sources such as animal dung are also used (cf. UNDP 2008). Yet this practice further withdraws organic material and nutrients from the agricultural system and has been associated with declining soil fertility (OECD/IEA 2007). While demand for cooking fuel is generally not considered as a main driver of deforestation (ibid.), it does increase pressure on forest ecosystems and requires a relevant share of household time allocated to firewood collection. Furthermore, firewood use as primary cooking fuel is associated to detrimental health effects through exposure to indoor pollution (WHO 2002).

8.4.2 Conventional Solutions: New Tensions and Trade-Offs

In relation to these sustainability challenges, a series of somewhat conventional solutions exists in terms of practices that are either commonly proposed or commonly employed to overcome challenges of the smallholder economy. These are, for example, green revolution techniques to close the yield gap and to fully exploit available agricultural land (Godfray et al. 2010). They also include rural-urban migration to seek new incomes with higher economic returns in other economic sectors (Hecht 2010; Kelly 2011), as well as the replacement of traditional biomass cooking fuels by modern energy forms such as Liquefied Petroleum Gas (LPG), stoves and cylinders (UNDP 2008). Yet such conventional development pathways produce a series of new tensions and trade-offs across other sustainability domains.

The most commonly proposed solution to enhance the agricultural enterprise is closing of the yield gap through green revolution techniques, i.e. through modernization of irrigation, fertilization and introduction of high yielding seed varieties. It is out of our scope to review the broader implications and limitations of such techniques for development and the environment here.[5] However, from a nexus perspective we briefly highlight the direct implications of increasing fertilizer use by creating new pressures across other sustainability dimensions (Fig. 8.2).

Figure 8.2 shows the paddy rice metabolism of the village economy in relation to actual and potential fertilizer use, embedded in a series of biophysical constraints, economic dynamics and decisions to be made by the farmers. Paddy rice production is limited by biophysical constraints in terms of the amount of agricultural land that can be accessed by the villagers (Fig. 8.2a). As of 2011, available agricultural land comprised 170 ha of paddy land located within the village, plus 11 ha of paddy land rented from surrounding villages. Given that currently no more village land can be colonized for agriculture, and that land has become scarce regionally and countrywide, land is assumed here as a biophysical constraint that cannot easily be overcome by colonizing new land or further ‘importing’ land from neighbouring areas. Hence, changing the quantity of land use is unlikely, but rather changes in the quality and management of land use can be expected in order to increase production.

However, decisions on increasing fertilizer use (Fig. 8.2c) to boost yields also depend on economic constraints, i.e. fertilizer costs, which during 2010–2011 were on average at 0.63$/kg of industrially produced fertilizer (Fig. 8.2b) (own survey data, see also Theng et al. 2014). The sale of larger shares of paddy produce during

[5] For a review and discussion see for example Pingali (2012) and Patel (2012).

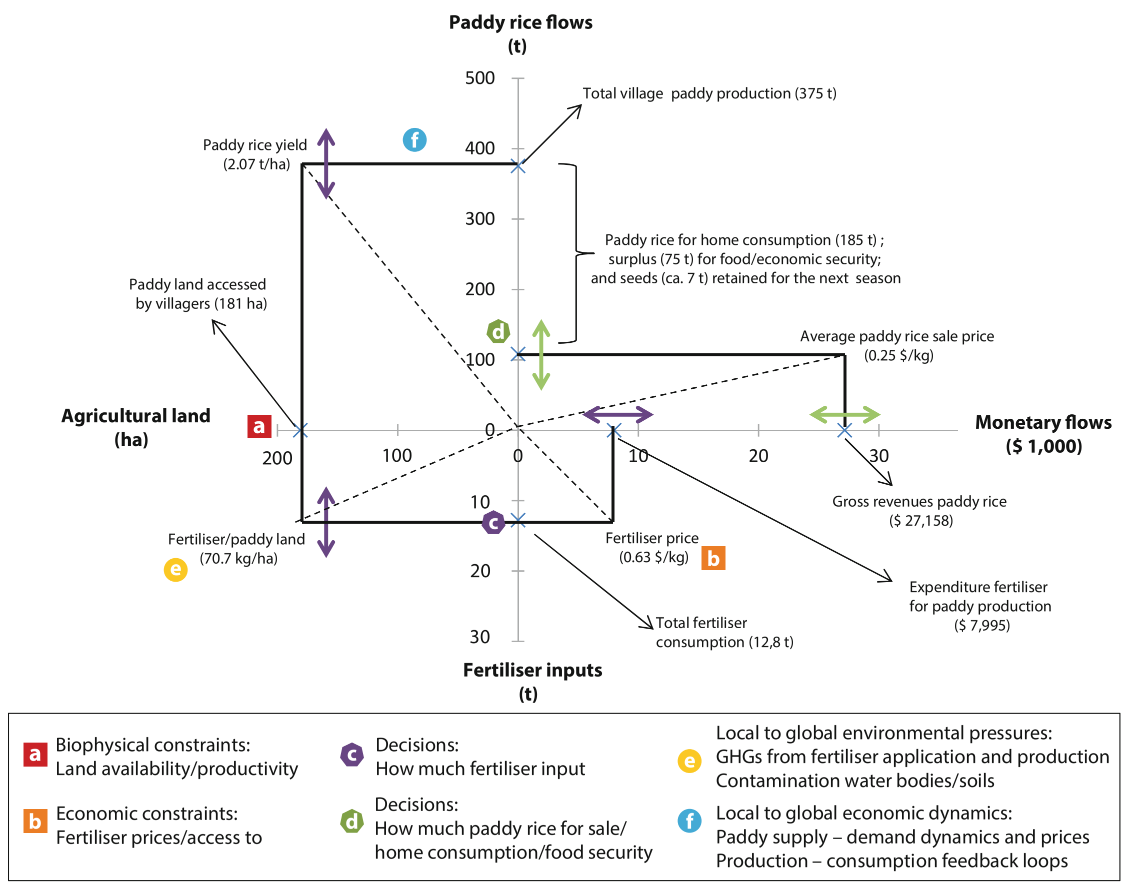

Fig. 8.2 The paddy rice metabolism of the small-farmer village, embedded in biophysical and economic constraints, farmers' decisions and potential pressures on the environment (2010–2011 agricultural year). Right X-axis = selected revenues and expenditures (1000$); Left X-axis = Agricultural land accessed by villagers (own land plus rented land); Upper Y-axis = Paddy production and sale (tons); Lower Y-axis = Total fertilizer input (tons). Small differences are due to rounding issues. *Source* Own elaboration based on survey data. GHGs = greenhouse gases

the previous year, to increase agricultural returns in order to be able to invest in agro-inputs, would create new tensions on food security, particularly for those households who produce below the village average (Fig. 8.2d and green arrows). For many farmers, the extra costs that fertilizers entail in fact pose a barrier to further usage, particularly when they face problems of limited surplus production and monetary liquidity such as in this village. In such cases, increased returns (higher yields) on investments (additional fertilizer costs) come too late to make it a viable option. Use of credits for buying inputs is an option, but further increases the economic burden, whereas a part of the increased paddy rice production would then just be used to repay interest rates of around 2–3%/month (Theng et al. 2014 see also Sect. 8.5.3). Further, rising yields cannot be expected to increase economic revenues linearly, as a growing paddy rice supply can also be expected to lower paddy rice prices due to supply-demand dynamics (Fig. 8.2f). In fact, in the village and other areas, it is common that paddy rice prices rise before harvest, when local supply falls short, and fall directly after harvest, when supply increases.

Beyond these economic dynamics, the adoption of such apparently simple green revolution techniques is directly linked to well-known environmental issues (Fig. 8.2e). Increasing fertilizer use drives environmental pressure on water bodies and soils (Tilman 1999). It also has relevant climate 'rucksacks' associated with fertilizer production, trade and application. Snyder et al. (2009) estimate that production and transport of 1 kg of N-fertilizer is associated with a Global Warming Potential (GWP) of more than 4 kg of CO_2. Further, application of 100 kg for rice cropping produces on average around 1.25 kg of the highly climate damaging trace gas N_2O, which corresponds to a GWP of 370 kg of CO_2 (Leisz et al. 2007). In a scenario in which the village increases fertilizer use to 100 kg/ha, the additional amount of fertilizers consumed (ca. 5.3 tons) would imply a roughly estimated additional GWP, through fertilizer production, transport and application, of more than 40,000 kg of CO_2/year. To make this value palpable, this corresponds to the emissions generated through driving a passenger car in Europe for more than 300,000 km.[6]

To sum up, the implications of green revolution techniques to close the yield gap are not straightforward or linear, but are rather embedded in complex system dynamics comprising biophysical, economic and social dimensions. As illustrated in Fig. 8.2, they are far more than just a simple technological fix. The fix triggers feedback loops within production and consumption of the socio-economic system, which may create new pressures across different dimensions. Such feedback-loops might in fact just result in a vicious cycle, where the amount of production indeed increases, but also intensification is further pushed to increase. While in such a scenario, environmental pressures may increase over time, economic returns for farmers do not necessarily follow due to system changes and consumption-production

[6]Comparisons to CO_2 emission from car driving are solely for illustrative purposes. They are based on the current maximum allowed EU limit value of 130 g CO_2/km for new cars, referring to the generation of CO_2 during its use (not including during the production of the car). http://ec.europa.eu/clima/policies/transport/vehicles/cars/index_en.htm.

feedback loops. As Tello and González de Molina (Chap. 2 in this volume) have stated, increased land and labour productivity achieved by the Green Revolution was historically generally accompanied by a steady decline of the net-value of production retained by farmers.

Similarly, other common solutions to other challenges also come with new trade-offs. For generating sufficient incomes, livelihood diversification and migration is playing an ever-increasing role (Ellis 2000; Kelly 2011). When it occurs out of necessity, because of lacking access to land rather than as a desired change pursued by rural dwellers, then the implications for the household may be manifold. They may include acceptance of badly paid jobs, or long-term migration with significant impacts on family relations, including the issue of who will take care of kids and the elderly. The future will show, how these rural changes, currently underway in Southeast Asia, play out, and what kind of new questions they will pose with regard to the sustainability of local food systems.

With regard to environmental challenges, particularly the demand for cooking fuels as discussed above, conventional development paths suggest a change in source, by moving from biomass to more modern types of energy sources, such as LPG stoves (OECD/IEA 2007; UNDP 2008). While this resolves some problems (i.e. pressure on forest ecosystems, human health) they also create new ones through replacing genuinely renewable energy sources with fossil ones, thus increasing dependency on externally supplied energy. From a nexus perspective, such trade-offs across dimensions and scales need to be carefully considered when imagining local sustainable food systems, in order to avoid the repetition of unsustainable development pathways, through which many countries have already gone.

8.5 Cooperative Initiatives to Support Sustainability of Local Food Systems

Biophysical constraints such as land shortage, in combination with other drivers of change, are posing severe challenges on the small farmer economy. Escapes from this situation, based on conventional development pathways, are not straightforward. Yet there are many new developments under way, which may allow local food systems in the global South to take a different pathway from the conventional agricultural development path. While in this context, the concept of leapfrogging has received much attention (Perkins 2003), it has been narrowly focused on technological solutions. Since resource uses are strongly embedded in complex socio-economic dynamics, local institutions and new sets of practices in how the local economy is organized do also have impacts on resource use patterns. In this final section, we report on five alternative and low-capital intense developments that have been pursued by villagers. Some of these are new technologies and agricultural techniques, and others represent new small-scale cooperative economic models. In this section we will review their functioning and their immediate implications on sustainability, as well as their adoption in the village and elsewhere in Cambodia (see Table 8.2 for an overview of their key requirements and key benefits from a sustainable food systems perspective).

8.5.1 System of Rice Intensification: Agroecological Techniques to Enhance Yields and Reduce Inputs

Some households have started to adopt the System of Rice Intensification (SRI), which is an agroecological rice cropping practice initially developed by poor farmers in Madagascar. It is comprised of a set of cropping techniques that help to save seeds, fertilizer and water, based on the use of traditional rice varieties (Uphoff 1999; Stoop et al. 2002). The set of practices can furthermore be adopted and combined according to farmers' possibilities. Practices include, for example, selection of the best seeds for sowing in a nursery bed; the transplanting of only good seedlings into the field; careful transplantation of single seedlings at the two-leaf stage; careful water management by keeping the soil moist; mulching the soil with organic matter; the use of compost; planting green manure; and selection of the best seeds for the next crop. Since its discovery, SRI has expanded globally and has been reported to have the potential to increase rice yields by up to 20–100%. At the same time, required seed inputs is argued to be reduced by up to 90% and water use by up to 50%.[7] SRI has received positive response in Cambodia since the turn of the millennium, when many Cambodian farmers started to adopt SRI techniques (Anthofer 2004).

SRI was initially promoted in the village through the NGO CEDAC (Cambodia Center for the Study and Development in Agriculture). Survey results suggested that during 2010–2011, around 10% of the households had used between three to eight SRI techniques on some parts of their land. In early 2016, the number of SRI farmers has grown to 44%. However, some of the more labour-intensive practices, such as transplantation of seedlings, were replaced by less labour-intensive practices.[8] While the reported cases are too few to provide significant and detailed evidence regarding differences in yields, labour inputs, and the like, the few SRI farmers that we interviewed did mention higher yields. This is in line with a countrywide study that showed a significant yield increase of 41% through SRI techniques, maintained over several years (Anthofer 2004).

---

[7]See SRI International Network and Resources Center, Cornell University: http://sri.cals.cornell.edu/.

[8]Transplantation of the seedlings is an agricultural technique through which farmers transplant seedlings from a nursery bed to the paddy field after finishing land preparation. It requires more time and effort than spreading the paddy seeds directly on the field. The latter method is mostly practiced on upland or less-watered rice fields. It is less time consuming, but associated with lower yields and higher seed inputs.

On the country level, the Ministry of Agriculture, Forestry and Fisheries (MAFF) started to support SRI by hosting the national SRI secretariat, which it has done since 2004. During 2012, at least 101,719 ha came under SRI management, corresponding to around 150,000–200,000 households (SRI-Rice 2015). The use of agroecological rice cropping techniques such as SRI is relevant for leapfrogging conventional green revolution techniques due to their reduced requirements on synthetic fertilizer, water and seeds. SRI further promotes the creation of place-based agroecological knowledge, whereas SRI farmers reported constantly trying out new methods or changing the set of techniques employed, according to their needs. However, in order to understand its sustainability potential, it is necessary to have a good understanding of farmers' reasons for adoption and non-adoption of SRI techniques (Moser and Barrett 2003; Ches and Yamaji 2016).

8.5.2 Small-Scale Biogas Production to Reduce Climate Gases, Firewood and Fertilizer Needs

The adoption of small-scale biogas systems had just started to spread in the village. Natural biodigesters represent a simple but innovative technology to produce biogas at the household level, based on human and animal manure. Such biogas systems consist of a small tank, constructed underground, with a capacity of 4–15 m^3 to process animal dung, humanure and other organic wastes through anaerobic digestion into methane gas (CH_4). The obtained biogas can be used for cooking and lighting. The fully digested waste can be further used as organic fertilizer; when compared to undigested manure, nutrients are generally better taken up by soils (KOICA/UNEP/CAPS 2011; NBP 2015).

During 2011, 5% of the village households reported having installed a natural biodigester thanks to a provincial support programme that provided $150 of subsidies for each installed digester. The most commonly adopted size was either 4 or 6 m^3, whereas construction costs amounted to $400 and $500 respectively. A 6 m^3 biodigester—the most commonly used in Cambodia (KOICA/UNEP/CAPS 2011)—can produce daily biogas up to 1.6–2.4 m^3, which corresponds to 4–6 h of biogas stove use, or 16–24 h of biogas lamp usage. Based on commonly used, low-tech wood stoves, 1 m^3 biogas can replace about 5 kg of firewood (NBP 2015). Based on the lower estimates of 1.6 m^3 daily biogas production (6 m^3 digester), monthly production would allow to save up to 240 kg of firewood, which covers household cooking fuel needs, while still allowing the use of biogas for lighting purposes. In early 2016, villagers reported that 15% of households had had biodigesters installed. While wired electricity has meanwhile reached the village, the adoption of small-scale biogas systems can be expected to further increase, as firewood continues to be a scarce resource, and households tend to use electricity for different purposes, such as lighting or watching TV.

On the country level, household biodigesters started to be promoted in 2006. Up to 2014, about 22,000 systems were installed across Cambodia, with 96% of the systems reported as still operating satisfactorily several years after installation. According to the NBP programme, a biodigester can save on average 50$/year of expenditure on chemical fertilizers, with 90% of all users reported to be applying the produced bio-slurry as organic fertilizer (NBP 2015). In summary, small-scale biodigesters bring benefits across multiple sustainability dimensions: reduction of firewood needs; decrease in climate aggressive methane emissions released during uncontrolled decomposition of livestock manure; enhanced applicability of manure as organic fertilizer; reduced time requirements for firewood collection, and improved health through reduction of indoor air pollution and increased sanitation. Economic benefits accompany lowered resource needs, i.e. through reducing expenditures on fertilizers and firewood. With regard to the sustainability of local food systems, biodigesters thus support a cascading resource use and closing of local nutrient cycles. They further show a strong potential for leapfrogging conventional development pathways through avoiding a transition to fossil-fuelled cooking and lighting fuels such as LP gas.

8.5.3 Community Banking to Acquire New Assets and Avoid Capital Outflow

The adoption of new assets, such as a biodigester, also requires access to financial capital. In order to foster household saving as well as community access to cheaper credits, the villagers established a small-scale cooperative banking (SSCB) system, also known as community finance, savings groups, or credit unions (Evans and Ford 2003). Similar to those credit unions established by European farmers during the mid 19th century (Fairbairn 1991; Goglio and Leonardi 2010), such cooperative savings groups establish a community fund through pooling of individual savings, in order to provide credits at defined terms to members. Savings, credits and interest rates are managed under a well-defined set of institutional agreements which is established, maintained and modified by all-members meetings and by a SSCB committee, elected democratically every three years. After learning and participating in the group, members can access cheaper loans than from external micro-credit. They may serve not only to solve short-term needs for credit, but also to expand their income sources through investment in new livelihood activities, such as livestock raising or the growing of vegetables to diversify household production.

In early 2011, the SSCB group had 168 members. At the end of the 2010 banking year, the total capital fund, pooled from individual savings, amounted to about $35,000. Based on this capital fund, credits were provided to villagers that allowed them to diversify their livelihood activities through investment into additional livelihood assets, as well as to overcome transitory money shortages. The interest rate was democratically set around 1 percentage point lower per month than external micro-credit providers: during 2010 it was at 3%/month. In 2011 it was reduced to 2.5%/month, with a lowered interest rate of 2%/month for poor households.[9] While these rates still seem high, they are below global averages of micro-credit interest rates (Kneiding and Rosenberg 2008). Furthermore, the returns from interest payments stay in the village instead of flowing out to external micro-credit providers, thus supporting village capitalization (Ward and Lewis 2002). Since its establishment, the group has developed well and in early 2016, it reported 228 members and a capital of 680 million Riels (more than $166,000).

In rural Cambodia, where farmers have expressed high credit needs (ADB 2001; Ballard 2006), such a kind of savings-led microfinance has become increasingly widespread to provide farmers with access to financial services. Such groups were actively promoted through NGOs like CEDAC or Oxfam. Oxfam, for instance, started a promotion initiative in 2005 and since then has reached approximately 110,000 farmers that became members of 6000 groups, with the majority of the members being women (Oxfam 2014). Saving groups have become increasingly relevant to farmers across Cambodia and now there has been increased focus on the sustainability of these groups, particularly regarding the achievement of autonomous functioning after promoting agencies phase out (EMC 2015).

While such savings groups do not necessarily avoid the dynamics of debit and credit, which can produce or reinforce local inequalities, they also have environmental implications. As Gerber (2013) argues, credit and related interest rates may have detrimental effects on the environment as the need to repay high interest rates, in addition to the initial credit capital, further generates the need for increased surplus production. This may further lead to higher rates of biomass extraction based on (unsustainable) agricultural intensification, which may be associated with environmental degradation through the discharge of agro-chemicals into the environment. Having democratic control over financial resources and services may allow the lowering of interest rates, in comparison with conventional micro-credit providers, as well as the ability to make decisions about which types of credits are granted. Savings groups may thus allow dampening interest rate pressures on resource extraction and the environment (Scheidel and Farrell 2015).

8.5.4 The Cooperative Paddy Rice Bank: Overcoming Transitory Food and Seed Shortages

To deal explicitly with food and seed shortages, that may appear before the new harvest or when rice prices are high, the village community established a paddy rice bank. Initially supported by German's technical cooperation agency (GIZ), with

[9]Interest rates are as reported by community representatives and not inflation adjusted. Annual inflation in Cambodia was at 4.00 and 5.48% in 2010 and 2011, respectively (World Bank 2015).

shared knowledge, a storage place and a start-up paddy rice capital fund, the paddy rice bank provides rice credits to villagers that have become short on food. Rice credits need to be repaid with interest rates, which are also paid in paddy rice. Similar to the cooperative bank, it is democratically managed by the villagers themselves, based on a defined set of local institutional agreements.

In 2010, the bank had 190 members (rice borrowers) and a paddy rice stock of 28 tons, of which 7 tons were provided as rice credits to villagers. Based on average paddy rice consumption values of 223 kg/cap/year (ACI 2005), the total stockpile could ensure staple food security for around 126 persons during a full year. Interest rates amounted to half a basket of rice (ca. 12 kg) for every three baskets borrowed, equalling an interest rate of 16%. This was also the maximum amount a villager could borrow. Each borrower required up to five persons from other households who agree to share the liability of paying the rice back. A small part (6%) of the total benefits created from interest payments were used to compensate the efforts of the rice bank committee in maintaining the cooperative. The remaining share was largely used to support community activities such as the repairing of roads or dams. Although the number of members has declined over recent years, in 2016, the paddy rice bank was still active, with around 78 members and approx. 26 tons of paddy rice stock. 10 tons of paddy rice stock was previously sold by the community to finance repairs and the construction of a water dam benefitting the whole village.

Such small paddy rice banks have been commonly supported across Cambodia by NGOs, which provided a small paddy rice stock to assist with rice production. Initially, only a small number of families were allowed to borrow paddy rice, which they had to return after harvest season for paddy rice production. Interest rates were used to increase local paddy rice stocks, with between 5 and 10% of the interest generally being retained to develop their local areas with projects such as roads, canals and so on. In operation since 2003, with the support of the government and NGOs, more than 12,000 Cambodian families were reported to have joined such groups. The paddy rice stocks of small paddy rice banks across Cambodia have increased steadily, with several thousand tonnes of paddy rice being stockpiled in rural areas to support villagers.

Regarding the sustainability of local food systems, this cooperative bank helps to overcome problems of ‘paddy rice liquidity’ as well as to increase village food sovereignty, by facilitating at defined rules the allocation of paddy rice flows between harvests (time) as well as between households (space). In contrast to the role of local markets in the distribution of rice production, the paddy rice bank is under democratic control, avoiding price volatility, speculation, and the exit of rice flows in periods of scarcity. It is also an important alternative to external credit or agricultural intensification in overcoming transitory shortages. However, it also produces a situation in which the poorer households—in terms of those lacking access to land for sufficient food production—are financing village community activities through their paddy rice interest payments. This is a drawback that should be considered. The lowering of interest rates to a minimum may help to reduce such negative social aspects.

8.5.5 Rice Mill Associations to Increase Market Performance and Use of Valuable Organic Residuals

The establishment of a rice mill association in the neighbouring village represents another interesting development. It was set up to enhance and stabilize paddy rice prices through collective rice trade, and to enhance market performance by producing high-quality milled rice. The association was established in 2008 with support from NGOs, and is now managed through farmers who have invested to become shareholders. The Ministry of Agriculture, Forestry and Fisheries (MAFF) acknowledged the association in June 2009 and provided initial funds of 1,500,000 Riels (around $365) and a rice milling machine. Members initially came from 11 villages in 5 different districts.

The association buys rice from its members and other farmers at a stable price, this is then sold collectively, either as paddy or as milled rice. Hence it acts as a 'paddy rice cartel' to increase bargaining power, enabling farmers to increase their share in the food value chain. In addition, the rice mill association also provides credits to villagers and initially also conducted other activities such as seed conservation, which, however, was stopped due to a lack of resources. 70% of the benefits generated from trading rice and providing credits are split among the shareholders, whereas 17% is distributed among the democratically elected committee members as compensation for their management efforts. 10% are further retained for maintenance of the rice mill infrastructure and 3% are retained for capacity building activities. In 2016, the president reported that the association was still active with a total of 37 members and a shareholder capital of 30 million Riels (ca. $7300). Trading of paddy rice had to stop during the previous year because of a lack of transport options. The total number of members decreased because some members living outside the district had joined other nearby rice mill associations that had been established in their areas. Yet, due to its secondary function as credit provider, the rice mill association has continued to be an active cooperative. Compared to other producer associations studied by the authors (cashew, cassava, handicraft associations), financial involvement seems to play an important role in assuring long-term commitment to local producers' associations.

In Cambodia, the rice marketing system is largely dominated by small traders and processors even though Cambodian rice is increasingly valued on international markets and export rates are growing fast. The changes in traded quantity were also accompanied by quality improvements through enhanced milling capacities, accompanied by the introduction of food safety certification programmes. Within this move from trading basic paddy to high-quality milled rice, small-scale rice mill associations as described above play an important role countrywide. They reduce intermediaries between producers and consumers and support small farmers to increase their shares of benefits along the rice value chain. This also has direct implications for resource use and sustainability. Firstly, achieving stabilization or even increases of paddy rice prices may help to avoid a race to the bottom among competing sellers of such primary commodities. Consequently, for the same

Table 8.2 Overview of cooperative and knowledge-based initiatives among Cambodian small farmers, their key requirements, and their key benefits from a sustainable food systems perspective

Initiative	Key requirements	Key benefits from a sustainable food systems perspective
System of rice intensification (SRI)	• Detailed knowledge and skills • May require additional labour, depending on adopted techniques	• Fosters place-based knowledge creation for agroecological fitness, enhanced yields and improved paddy quality • Reduces natural resource inputs, i.e., seeds, water • Reduces use of agro-chemicals and related GHG and fossil energy rucksacks attached to their production, trade and application
Small-scale biogas system (Biodigester)	• Basic knowledge • Low-capital investment (Biodigester construction)	• Enables cascading resource use and closing of nutrient cycles through enhanced manure/humanure management • Reduces GHG gases from enhanced manure/humanure management and reduced fossil fuel demand for cooking/lightening • Reduces firewood demand and pressures on forests • Frees labour time required for firewood collection • Reduces indoor pollution and health risks
Small-scale cooperative banking (SSCB)	• Detailed knowledge and skills • Cooperation between farmers	• Supports economic democratization of village capitalization and fairer participation of farmers in the financial economy • Avoids capital outflow from local interest payments to large microfinance corporations • Fosters saving and enhances access to (cheaper) credit • Supports acquisition of household assets, such as a biogas system
Paddy rice bank	• Detailed knowledge and skills • Cooperation between farmers • Low-capital investment: physical storage place	• Supports democratic control over community food storage • Increases food security at the village level • Supports community activities through food supply

(continued)

Table 8.2 (continued)

Initiative	Key requirements	Key benefits from a sustainable food systems perspective
Rice mill community	• Detailed knowledge and skills • Cooperation between farmers • Low to medium capital investment: storage place, rice milling facilities	• Supports economic democratization of paddy rice trade and fairer participation of farmers within the food trade chain through increasing farmers' share in the value chain, enhancement of their bargaining power, and reduction of intermediaries • Supports closing of nutrient cycles by retaining by-products such as rice husk for local uses • Supports conservation of local (traditional) seeds

Source Own elaboration. For further elaboration of the key benefits from a sustainable food systems perspective, see Tello and González de Molina, Chap. 2 in this volume

amount of biomass extraction (and associated environmental impacts) farmers may obtain higher economic returns than without the rice mill association. Secondly, farmers can retain biomass by-products, such as husk separated after milling, which have many useful applications, ranging from soil aeration in horticulture, to animal bedding, or compost production (Badar and Qureshi 2014). Considering that around 20% of paddy weight is husk (IRRI 2013), the village could theoretically retain up to 75 tons of extracted biomass for local uses, while further reducing need for synthetic fertilizers. Hence, the establishment of such cooperatively-managed distribution and trade channels may therefore further support local sustainable food systems through local nutrient cycling, reduction of intermediaries between producers and consumers, and increasing the economic benefits that small farmers may obtain from food trade.

8.6 Conclusions

Many small farmers in Cambodia and elsewhere face a difficult situation, trying to maintain and enhance their farming-based livelihoods, while keeping pressures on land, labour and the environment at bay. Land shortage is a key issue to be dealt with, and against the backdrop of a countrywide and global land grab crisis, it can be expected to remain a central challenge for rural dwellers over the next years. However, there are many new developments underway, able to support local food systems through a series of cooperative, knowledge-based and low-capital intensive initiatives. They offer important potentials to leapfrog more conventional development pathways and to support the sustainability of local food systems.

This chapter has particularly discussed the role that the System of Rice Intensification (SRI), small-scale biogas systems, a paddy rice bank, community finance and a rice mill association can play for farmers who, although facing severe land shortage, are still in control of their means of production. As a set of initiatives that have diffused, thanks to cooperation between farmers and NGOs, they can contribute to sustainable food systems through a series of processes. Particularly, SRI fosters place-based knowledge creation that supports agroecological fitness, enhanced yields and improved paddy quality, while lowering natural and synthetic farming inputs. The small-scale biogas system is a clever but simple invention to enable cascading resource use and closing of nutrient cycles through enhanced manure/humanure management. Reduced demand for firewood and the labour required for its collection, a decreased dependence on fossil energy demand for cooking, and reduced air pollution are just some of its benefits. Community banking of both financial capital and rice stocks are examples of how to enhance economic democratization regarding the management, access to, and use of community resources, while supporting a fairer participation of farmers in the financial economy. Finally, a community-operated rice mill association also helps farmers to have a fairer share of the food trade chain, while enabling them to retain by-products such as rice husk that support the closing of local nutrient cycles (Table 8.2).

As many of these alternatives have only recently found diffusion, it is difficult to identify their long-term potential for leapfrogging conventional agricultural development. Moreover, rural systems in the Global South are currently undergoing rapid transformations (Kelly 2011; Ravera et al. 2014). Yet their study will be increasingly important for further imagining a path towards local sustainable food systems. While, with regard to the question of leapfrogging, much attention has been paid to the diffusion of new and clean technologies, we have illustrated that it is further relevant to look at the diffusion of social innovations and cooperative initiatives. They do not require much capital or technology, but rather new skills and an enhanced understanding of models of local cooperative economies—including their implications for resource uses. While some of them are spreading fast thanks to an increasingly connected information and actor network, the future will show us the long-term benefits as well as the new challenges they may pose to local food systems.

References

ACI. (2005). Final Report for the Cambodian Agrarian Structure Study. Prepared for the Ministry of Agriculture, Forestry and Fisheries, Royal Government of Cambodia, the World Bank, the Canadian International Development Agency (CIDA) and the Government of Germany/G. Bethesda, Maryland.

ADB. (2001). *Participatory poverty assessment in Cambodia*. Manila: Asian Development Bank.

ADB. (2012). Technical Assistance Consultant' s Report: The Rice Situation in Cambodia.

Anthofer, J. (2004). *The potential of the System of Rice Intensification (SRI) for poverty reduction in Cambodia*, Berlin.

Badar, R., & Qureshi, S. A. (2014). Composted rice husk improves the growth and biochemical parameters of sunflower plants. *Journal of Botany, 2014,* 1–7. doi:10.1155/2014/427648.

Ballard, B. (2006). Land tenure database development in Cambodia. In M. Torhonen, P. Groppo (Eds.), *Land reform—Land settlement and cooperatives* (pp. 71–82). Food and Agriculture Organization (FAO).

CCHR. (2013). *Cambodia: Land in conflict. An overview of the land situation*. Phnom Penh.

Chandler, D. (2008). *A history of Cambodia* (4th ed.). Boulder: Westview Press.

Ches, S., & Yamaji, E. (2016). Labor requirements of system of rice intensification (SRI) in Cambodia. *Paddy and Water Environment, 14,* 335–342. doi:10.1007/s10333-015-0503-1.

Diepart, J.-C. (2015). *The fragmentation of land tenure systems in Cambodia: Peasants and the formalization of land rights*. Paris.

Ellis, F. (2000). The determinants of rural livelihood diversification in developing countries. *Journal of Agricultural Economics, 51,* 289–302. doi:10.1111/j.1477-9552.2000.tb01229.x.

EMC. (2015). *Sustainability study of savings group programs in Cambodia for CARE, Oxfam, and Pact*. Phnom Penh.

Erb, K. H. (2012). How a socio-ecological metabolism approach can help to advance our understanding of changes in land-use intensity. *Ecological Economics, 76,* 8–14. doi:10.1016/j.ecolecon.2012.02.005.

Evans, A., & Ford, C. (2003). *A technical guide to rural finance*. Madison: World Council of Credit Unions.

Fairbairn, B. (1991). *Farmers, capital, and the state in Germany, c. 1860–1914*. Saskatoon: University of Saskatchewan.

FAO. (2015). *FAO Statistical Databases*. Food and Agriculture Organization of the United Nations.

Georgescu-Roegen, N. (1971). *The entropy law and the economic process*. Cambridge, London: Harvard University Press.

Gerber, J.-F. (2013). The hidden consequences of credit: An illustration from rural Indonesia. *Development and Change, 44,* 839–860. doi:10.1111/dech.12045.

Giampietro, M. (2003). *Multi-scale integrated analysis of agroecosystems*. Florida: CRC Press LLC.

Giampietro, M., & Mayumi, K. (2000a). Multiple-scale integrated assessment of societal metabolism: Introducing the approach. *Population and Environment, 22,* 109–153.

Giampietro, M., & Mayumi, K. (2000b). Multiple-scale integrated assessments of societal metabolism: Integrating biophysical and economic representations across scales. *Population and Environment, 22,* 155–210.

Giampietro, M., Mayumi, K., & Ramos-Martin, J. (2009). Multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM): Theoretical concepts and basic rationale. *Energy, 34,* 313–322.

Godfray, H. C. J., Beddington, J. R., Crute, I. R., et al. (2010). Food security: The challenge of feeding 9 billion people. *Science, 327*(80), 812–818.

Goglio, S., & Leonardi, A. (2010). *The roots of cooperative credit from a theoretical and historical perspective*. Trento: European Research Institute on Cooperative and Social Enterprises.

Gomiero, T., & Giampietro, M. (2001). Multiple-scale integrated analysis of farming systems: The Thuong Lo Commune (Vietnamese Uplands) case study. *Population and Environment, 22,* 315–352.

Gotaas, H. B. (1956). Composting: Sanitary disposal and reclamation of organic wastes. Geneva: World Health Organization (WHO).

Grimsditch, M., & Schoenberger, L. (2015). *New actions and existing policies: The implementation and impacts of Order 01*. Phnom Penh.

Grünbühel, C., & Schandl, H. (2005). Using land-time-budgets to analyse farming systems and poverty alleviation policies in the Lao PDR. *International Journal of Global Environmental Issues, 5,* 142–180.

Hecht, S. (2010). The new rurality: Globalization, peasants and the paradoxes of landscapes. *Land Use Policy, 27,* 161–169.

Heuveline, P. (1998). "Between One and Three Million": Towards the demographic reconstruction of a decade of Cambodian history (1970–79). *Population Studies (New York), 52,* 49–65. doi:10.1080/0032472031000150176.

IRRI. (2013). *A second life for rice husk*. Rice Today April–June.

Jiao, X., Smith-Hall, C., & Theilade, I. (2015). Rural household incomes and land grabbing in Cambodia. *Land Use Policy, 48,* 317–328. doi:10.1016/j.landusepol.2015.06.008.

Kelly, P. F. (2011). Migration, agrarian transition, and rural change in Southeast Asia. *Critical Asian Studies, 43,* 479–506. doi:10.1080/14672715.2011.623516.

Kneiding, C., & Rosenberg, R. (2008). *Variations in microcredit interest rates*. CGAP policy brief, July 2008.

KOICA/UNEP/CAPS. (2011). *Biogas digesters for Cambodians: A multi-partner national biodigester program in Cambodia*.

Leisz, S. J., Rasmussen, K., Olesen, J. E., et al. (2007). The impacts of local farming system development trajectories on greenhouse gas emissions in the northern mountains of Vietnam. *Regional Environmental Change, 7,* 187–208. doi:10.1007/s10113-007-0037-1.

Leuprecht, P. (2004). *Land concessions for economic purposes in Cambodia. A human rights perspective*. Special Representative of the Secretary General of Human Rights in Cambodia, Phnom Penh.

Licadho. (2009). *Land grabbing and poverty in Cambodia: The myth of development*. LICADHO—Cambodian League for the Promotion and Defense of Human Rights, Phnom Penh.

Licadho. (2015). Cambodia's concessions. http://www.licadho-cambodia.org/land_concessions/. Accessed 23 Nov 2015.

MAFF. (2014). *Ministry of Agriculture, Forestry and Fisheries (MAFF)*. http://www.maff.gov.kh/index.php/overview.html. Accessed 12 June 2016.

Mayer, A., Schaffartzik, A., Haas, W., & Sepulveda, A. R. (2015). *Patterns of global biomass trade: Implications for food sovereignity and socio-environmental conflicts*.

Moser, C. M., & Barrett, C. B. (2003). The disappointing adoption dynamics of a yield-increasing, low external-input technology: The case of SRI in Madagascar. *Agricultural Systems, 76,* 1085–1100.

NBP. (2015). *National Biodigester Programme Cambodia*. http://nbp.org.kh/Default.aspx?lang=en. Accessed 19 May 2016.

NCDD. (2009). *Kampot Data Book*. Phnom Penh: National Committee for Sub-National Democratic Development (NCDD).

NIS. (2007). *Cambodia socio-economic survey 2004—Time use in Cambodia*. Phnom Penh, Cambodia: National Institute of Statistics (NIS), Ministry of Planning.

NIS. (2008). *Cambodia general population census 2008*. Phnom Penh, Cambodia: National Institute of Statistics (NIS), Ministry of Planning.

NIS. (2010). *Cambodia socio-economic survey 2009*. Phnom Penh, Cambodia: National Institute of Statistics (NIS), Ministry of Planning.

NIS. (2015). *Census of agriculture of the Kingdom of Cambodia 2013*. Phnom Penh.

OECD/IEA. (2007). Chapter 15 Energy for cooking in developing countries. In *World Energy Outlook 2006* (pp. 419–445). Paris: International Energy Agency (IEA) and Organisation for Economic Co-operation and Development (OECD).

Oxfam. (2014). *Study on women's empowerment and leadership in saving for change groups in Cambodia*.

Pastore, G., Giampietro, M., & Ji, L. (1999). Conventional and land-time budget analysis of rural villages in Hubei Province, China. *CRC Critical Reviews in Plant Sciences, 18,* 331–357.

Patel, R. (2012). The long green revolution. *The Journal of Peasant Studies, 6150,* 1–63. doi:10.1080/03066150.2012.719224.

Perkins, R. (2003). Environmental leapfrogging in developing countries: A critical assessment and reconstruction. *Natural Resources Forum, 27,* 177–188. doi:10.1111/1477-8947.00053.

Pingali, P. (2012). Green revolution: Impacts, limits, and the path ahead. *Proceedings of National Academy of Sciences, 109,* 12302–12308. doi:10.1073/pnas.0912953109.

Ravera, F., Scheidel, A., Dell'Angelo, J., et al. (2014). Pathways of rural change: An integrated assessment of metabolic patterns in emerging ruralities. *Environment, Development and Sustainability, 16,* 811–820. doi:10.1007/s10668-014-9534-9.

Scheidel, A. (2013). *From MuSIASEM theory to practice: Reflections and experiences from field research in Kampot Province, Cambodia*. Working Paper on Environmental Sciences. Institute of Environmental Science and Technology (ICTA) Autonomous University of Barcelona (UAB), Barcelona.

Scheidel, A. (2016). Tactics of land capture through claims of poverty reduction in Cambodia. *Geoforum, 75,* 110–114. doi:10.1016/j.geoforum.2016.06.022.

Scheidel, A., & Farrell, K. N. (2015). Small-scale cooperative banking and the production of capital: Reflecting on the role of institutional agreements in supporting rural livelihood in Kampot, Cambodia. *Ecological Economics, 119,* 230–240. doi:10.1016/j.ecolecon.2015.09.008.

Scheidel, A., Farrell, K. N., Ramos-Martin, J., et al. (2014). Land poverty and emerging ruralities in Cambodia: Insights from Kampot province. *Environment, Development and Sustainability, 16,* 823–840. doi:10.1007/s10668-014-9529-6.

Scheidel, A., Giampietro, M., & Ramos-Martin, J. (2013). Self-sufficiency or surplus: Conflicting local and national rural development goals in Cambodia. *Land Use Policy, 34,* 342–352. doi:10.1016/j.landusepol.2013.04.009.

Scurrah, N., & Hirsch, P. (2015). *The political economy of land governance in Cambodia*, 23.

Serrano-Tovar, T., & Giampietro, M. (2014). Multi-scale integrated analysis of rural Laos: Studying metabolic patterns of land uses across different levels and scales. *Land Use Policy, 36,* 155–170. doi:10.1016/j.landusepol.2013.08.003.

Singh, S. J., Ringhofer, L., Haas, W., et al. (2010). *Local studies manual—A researcher's guide for investigating the social metabolism of local rural systems*. Vienna: Institute for Social Ecology, IFF Vienna, Alpen-Adria University of Klagenfurt.

Snyder, C. S., Bruulsema, T. W., Jensen, T. L., & Fixen, P. E. (2009). Review of greenhouse gas emissions from crop production systems and fertilizer management effects. *Agriculture, Ecosystems & Environment, 133,* 247–266. doi:10.1016/j.agee.2009.04.021.

SRI-Rice. (2015). SRI International Network and Resources Center, Cambodia. In Cornell University—College of Agriculture and Life Science. http://sri.ciifad.cornell.edu/countries/cambodia/. Accessed 20 May 2016.

Stoop, W. A., Uphoff, N., & Kassam, A. (2002). A review of agricultural research issues raised by the system of rice intensification (SRI) from Madagascar: opportunities for improving farming systems for resource-poor farmers. *Agricultural Systems, 71*, 249–274.

Theng, V., Khiev, P., & Phon, D. (2014). *Development of the fertiliser industry in Cambodia: Structure of the market, challenges in the demand and supply sides, and the way forward*. Phnom Penh.

Tilman, D. (1999). Global environmental impacts of agricultural expansion: The need for sustainable and efficient practices. *Proceedings of the National Academy of Sciences of the United States of America, 96,* 5995–6000. doi:10.1073/pnas.96.11.5995.

UNDP. (2008). *Residential energy demand in rural Cambodia: An empirical study for Kampong Speu and Svay Rieng*.

Uphoff, N. (1999). Agroecological implications of the system of rice intensification (SRI) in Madagascar. *Environment, Development and Sustainability, 1,* 297–313.

Ward, B., & Lewis, J. (2002). *Making the most of every pound that enters your local economy*. London: The New Economics Foundation (NEF).

WHO. (2002). *The health effects of indoor air pollution exposure in developing countries*. Geneva.

World Bank. (2015). *Data Catalog*.

Yusuf, A. A., & Francisco, H. (2009). *Climate change vulnerability mapping for Southeast Asia*. Singapore.

Author Biographies

Arnim Scheidel is currently a postdoctoral researcher at the International Institute of Social Studies (ISS), The Hague, the Netherlands. He maintains close ties as affiliated researcher with the Institute of Environmental Science and Technology (ICTA), the Autonomous University of Barcelona (UAB), Spain, where he worked as researcher from 2010 and received his Ph.D. in Environmental Sciences in 2013. His general research interests include rural change, food system research, societal metabolism and ecological economics, with a particular focus on better understanding the political ecology of development and the emergence of alternative grassroots practices. Geographically, Arnim's focus has been on Southeast Asia as well as Europe, where he has done extensive research stays and field work. He is also an active contributor to the Atlas of Environmental Justice (EJatlas).

Bunchhorn Lim received his Bachelor degree in 2011 from the Faculty of Agricultural Economics and Rural Development at the Royal University of Agriculture (RUA), Phnom Penh, Cambodia. Currently, he is continuing his training with a Master's in Business Administration (MBA) at Norton University, Phnom Penh. He was a research assistant at the Economic Institute of Cambodia from 2012 to 2013 and now works in the Trade Development office at the governmental Department of Commerce in Kampong Thom province. His professional work and research interests include rural livelihoods and household economics, where he has done extensive research in Kampot province. More recently, he has started to study the market development of agri-products in Kampong Thom Province and is interested in understanding how related value chains can be improved for local farmers.

Kimchhin Sok is a researcher and lecturer at the Ecosystem Services and Land Use research center (ECOLAND) and the Faculty of Agricultural Economics and Rural Development of the Royal University of Agriculture (RUA) in Cambodia. Currently, he is finishing his Ph.D. in Economics and Management Science at the University of SupAgro Montpellier in France. In the past, he graduated with a Bachelor's and a Master's degree in agro-socioeconomics. Before and during his Master's research, he was involved in ecosystem services and agrarian systems research in his country, Cambodia, as well as in Burkina Faso, Morocco, France, and Myanmar. His education and research interests are related to the topics of the transition of agrarian/agricultural systems, household economies and livelihoods, and ecosystem services in the context of developing societies, with the aim of supporting sustainable development and natural resources conservation. At ECOLAND of RUA, he is also the secretary and a researcher.

Piseth Duk has been a researcher and lecturer at the Faculty of Agricultural Economics and Rural Development, Royal University of Agriculture (RUA), Phnom Penh, Cambodia. His research and teaching interests include rural regional management and livelihoods, agricultural development and land use planning. He recently turned from theory to practice and opened the De Burlap Cafe in Phnom Penh, where delicious and locally grown food is served.