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SYNERGIES AND TRADE OFFS WITH INTENSIFICATION OF RICE AND LIVESTOCK PRODUCTION IN CAMBODIA

Introduction

Agriculture is a high priority for the government's national development agenda (MAFF 2015). The main agricultural activities are rice, subsidiary and industrial crops, poultry and livestock. Rice is the principal crop, and there are four main rice ecosystems in Cambodia: rain-fed upland, rain-fed lowland, dry season irrigated, and floating and recession rice (Ros, Chhim and Nang 2011). The near-natural and formerly predictable nature of the extensive wet season flooding of the floodplains in the Mekong River Basin in Cambodia has supported flood recession agriculture. This involves small-scale farmers producing annual crops like rice as well as harvesting fish and other wild foodstuffs.

Sacks of rice readied for export to Vietnam. Takeo, Feb 2017

The natural flood flows are changing, particularly due to the existing and planned construction of hydropower dams in the basin. The Cambodian government plans to extensively expand regulated, infrastructure-based irrigated agriculture to enable production of two to three rice crops a year and increase milled rice export. From 2009 to 2013, the Ministry of Water Resources and Meteorology (MOWRAM) expanded irrigation coverage to provide water for an additional 387,907 ha of agricultural land. By 2013, the total irrigated area had increased to 1,485,670 ha (NSDP 2014-18).

We hypothesise that this change may result in increased production of rice but decreased production of other foodstuffs important in the diet of Cambodians. Hence it may favour commercial

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farmers at the expense of the livelihoods and nutritional security of subsistence farmers. Further, expansion of irrigated agriculture will require much greater use of resources such as energy and water that have not been modelled and may amount to negative impacts on other values. It will definitely increase the use of fertilisers and pesticides as the rice varieties capable of faster and bigger yields also require more of these inputs.

Therefore, the research question for this study is: what are the benefits, costs and risks of changing food production from flood recession to regulated, irrigated agriculture in Cambodia, considering food production, land, water, energy and household nutrition security?

Methodology

The research used a combined quantitative and case study approach. Scenario analysis synthesised and interpreted secondary data from many sources to estimate and compare food and nutritional supplies, yields, input (water, energy, fertiliser, labour, pesticide) requirements, and the benefits, costs and risks of one double rice and two integrated rice-fish farming systems. The quantitative results were supplemented with research evidence and observations from extension projects and case studies in Cambodia of when farmers can access good support, training and best practices or new technologies, namely system of rice intensification (Tech 2014; Anthofer 2004) and community fish refuges (Brooks and Sieu. 2016; Thouk 2009). Data on model vegetable farmers was not available, so the study used data on the highest vegetable yields attained in 2015 (MAFF 2016) based on the assumption that farmers were able to achieve high yields as a result of training and special support. The quantitative approach comprised several steps, as follows:

Food and nutritional supply calculation. The following formula was adapted from FAO (2001) based on available data to determine supplies of rice, bovine meat, ricefield fish, other aquatic animals (OAA) and vegetables. Food supply was divided by harvest/pasture area to determine food supply per hectare.

food supply = production + import – export +/- stock - feed - seed - food manufacture - waste - other use

Supplies of paddy, vegetables and bovine meat were calculated using FAOSTAT data (2016). Ricefield fish and OAA supplies were calculated based on data from six studies in Cambodia (Gregory, Guttman and Kekputhearith 1996; Nesbitt 1997; Guttman 1999); Troeung et al. 2003; Hortle, Troeung and Lieng 2008; Thouk 2009).

The study relied mainly on FAO's (1953, 1981) food composition tables to estimate nutritional supplies of protein, calories and lysine per hectare of rice, bovine meat, ricefield fish, OAA and vegetables (Table 1).

Potential production area projection. Using ArcGIS and crop area maps (IRRA 2010; ODC 2015, 2016), the current irrigated single-crop rice area was chosen as the potential area for irrigated double rice cropping (see Figure 1).

Table 1: Average protein, calorie and lysine content per 100 g by food type

Food stuff	Protein (g/100g)	Calories (cals/100g)	Lysine (mg/100g)
Ricefield fish (all fish, unspecified)	18.80[a]	132[b]	1713[a]
Other aquatic animals	16.00[c]	103[b]	1262[c]
Bovine meat (excl. kidney fat [1.8%])	17.70[a]	256[b]	1573[a]
Rice (husked or brown)	7.50[a]	357[b]	299[a]
Vegetables	2.03[d]	27[b]	100[d]

Sources: [a] FAO 1981; [b] FAO 1953; [c] Nurhasan et al. 2010; [d] Pittock, Dumaresq and Orr 2015

Production/yield estimation. MAFF annual reports provided data for both-season paddy yield (1980-2011), dry-season paddy yield (1980-2015), wet-season paddy yield (1980-2015), ricefield fish production (2008-2015), wet-season rice harvest area (2008-2015), vegetable yield (1996-2015), and milled rice supply (2008-09). This data was used to calculate protein, calorie and lysine production.

Input estimation. Data was compiled from several sources to estimate water consumption (Abrams 2015), energy consumption for rice (Islam et al. 2011), vegetable production (Canakci et al. 2005), fertiliser use (Theng et al. 2014), pesticide and labour costs (World Bank 2015).

Scenario modelling. Three scenarios were designed to compare current food supplies, projected protein, calorie and lysine production, water use, fertiliser use, energy consumption, labour and pesticide costs in the potential production area under three farming systems:

- Scenario 1: double rice cropping (wet- and dry-season rice)
- Scenario 2: wet-season rice / ricefield fish / OAA / bovines
- Scenario 3: wet-season rice / ricefield fish / OAA / vegetables

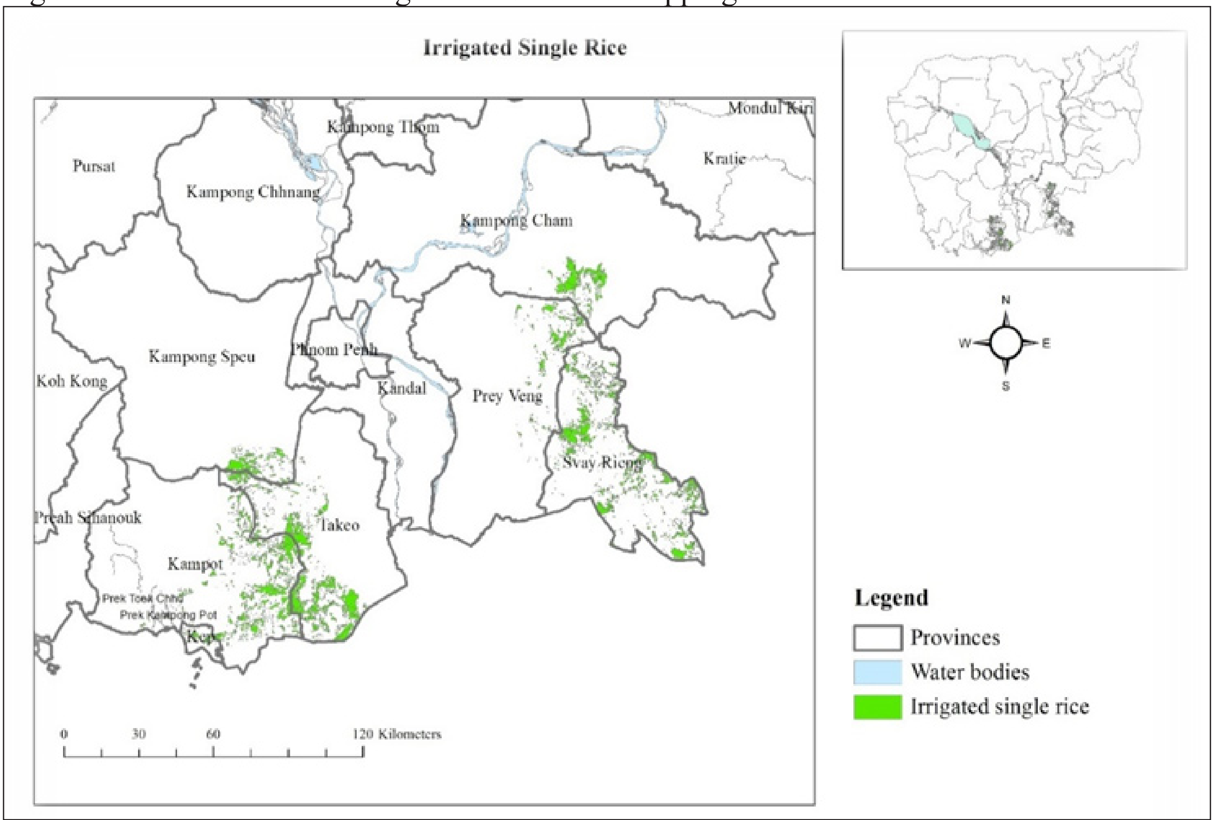
Scenario 1 was chosen to reflect conventional agricultural intensification. The other two were selected to reflect integrated farming systems that might be more sustainable for farmers: after harvest, the rice fields are either used to graze cattle or grow vegetables. All three scenarios were run a second time to compare the same criteria with and without the adoption of best practices and new techniques.

Key results

Table 2 presents the current food supply per hectare estimates for each scenario. As expected, scenario 2 produces less than the other scenarios. Although ricefield fish, OAA and meat provide more nutrition than rice, production combined with wet season rice is relatively low. Scenario 1 produces the most calories of all three because rice provides a lot of calories. However, scenario 3 is best in terms of protein and lysine, and produces almost double the lysine of scenario 2.

The current rice areas with potential for irrigated double rice cropping amount to 125,724 ha (Figure 1). Table 3 presents the projected trends for food

Figure 1: Potential area for irrigated double rice cropping



Source: IRRA 2010

Table 2: Total annual supply per hectare of protein, calories and lysine by food type

Food type	Scenario 1			Scenario 2			Scenario 3		
	Protein (t)	Calories (kcals)	Lysine (t)	Protein (t)	Calories (kcals)	Lysine (t)	Protein (t)	Calories ('000 kcals)	Lysine (t)
Rice	0.12	5880	0.005	0.060	2940	0.0020	0.060	2940	0.0020
Bovine meat	-	-	-	0.009	0.136	0.0010	-	-	-
Fish	-	-	-	0.020	0.150	0.0020	0.020	0.15	0.0020
OAA	-	-	-	0.004	0.030	0.0003	0.004	0.03	0.0003
Vegetables	-	-		-	-	-	0.100	1.35	0.0050
Total	**0.12**	**5880**	**0.005**	**0.093**	**3256**	**0.0053**	**0.184**	**4470**	**0.0093**

Table 3: Scenario modelling results for the potential area (125, 724 ha)

	Scenario 1	Scenario 2	Scenario 3
Projected annual food production, water, energy and fertiliser use, pesticide and labour costs			
Protein (t)	29475	15363	29898
Lysine (t)	900	729	1398
Calories (kcals million)	1403	559	751
Water use (mcm)	3017	1508	2451
Energy use (MJ million)	6726	3363	11059
Fertiliser use (t)	39176	13484	43938
Pesticide cost (USD)	2.01 m	503000	10.81 m
Labour cost (USD 4.56/day)	43.59 m	15.91 m	113.28 m
Projected annual food production, with training, technology/best practice adoption			
	+SRI	+CFR	+CFR + high veg yield
Protein (t)	90521	170976	192842
Lysine (t)	2764	14908	15939
Calories (kcals million)	4309	1652	1942

Note: SRI = system of rice intensification; CFR = community fish refuges.

production in terms of protein, calories and lysine in the entire potential area.[1]

Discussion

Benefits, costs and risks

Scenario 1: The benefits of double rice cropping are income from rice export, the highest food supply and production of calories, and the second highest food supply and production of protein and lysine. However, water costs are the highest and energy, fertiliser, and labour costs the second highest among the three scenarios.

The very high water requirement in this scenario poses the greatest risk, especially given the adverse impacts of hydropower dams and climate change on the quantity and quality of water resources. Ensuring a stable water supply and mitigating water supply risk in irrigated agriculture is costly as it requires irrigation infrastructure and institutional mechanisms.

Operating an irrigation system/water pumps also consumes a substantial amount of energy, although total energy requirement is lower than in scenario 3. Alternative energy sources would need to be considered.

1 In projection, we only estimate food production because we cannot project export and import needed for food supply calculation.

High fertiliser use associated with conventional intensive cropping can alter soil chemistry, damage soil structure and disrupt soil ecology. However, increased use of inorganic fertilisers in scenario 1 carries less risk than in scenario 3. Similarly, higher pesticide use stands to contaminate the environment (water, soil, air), degrade soil, harm non-target vegetation and organisms, and adversely affect human, animal and ecosystem health. Emissions of the greenhouse gases methane (CH^4) and nitrous oxide (N_2O), potent greenhouse gases in terms of their global warming potential (GWP), would increase under double paddy cropping. GWP would be higher than in scenario 3 with the application of fertiliser, or the same as in scenario 3 without the application of fertiliser.

If farmers were to adopt system of rice intensification (SRI) methods, double rice cropping could produce more food in terms of protein, calories and lysine, but using 50 percent less water. Also, energy costs would be lower, inorganic fertiliser use minimised, soil quality enriched and soil water conserved.

Scenario 2. Based on current per hectare food supply estimations, scenario 2 provides more lysine than scenario 1 but less than scenario 3. Projected lysine production in scenario 2 is slightly less than in scenarios 1 and 3, and projected protein and calorie production is much lower. Costs are the lowest among the three scenarios. The types of risks are the same but the degree of risk is lower than in the other two scenarios because scenario 2 has the lowest water and energy requirements and the lowest fertiliser and pesticide usage. If farmers were to adopt community fish refuges (CFR), the projected production of protein, calories and lysine in the potential area would increase.

*Scenario 3***.** Integrated wet-season rice/fish/OAA/vegetables provides the highest food supply and projected protein and lysine productions, and the second highest food supply and projected calories production. The four sources of protein can contribute to reducing stunting and underweight in Cambodia. The gross margin of vegetables in scenario 3 is higher than that for wet-season rice and dry-season rice, and vegetable production in this scenario can help meet domestic demand. However, scenario 3 has the highest energy, fertiliser, pesticide and labour costs, and the second highest water cost.

Water use and energy consumption are also high, so scenario 3 has similar risks as scenario 1. But the level of risk is lower because scenario 3 requires less water. Even so, scenario 3 is the biggest energy user. The implications of high-energy agriculture in the potential area are an important consideration.

Fertiliser and pesticide use in scenario 3 carry the same risks as in scenarios 1 and 2, but the level of risk is higher because vegetable crops require higher rates of fertiliser and pesticide application. Similarly, increased CH_4 and N_2O emissions from wet-season paddy and vegetables pose the same risk as from the farming systems in scenarios 1 and 2, but the level of risk is higher. However, if no inorganic fertilisers were applied, there would be no difference in risk between the scenarios. Finally, if farmers were to adopt CFR and produce high vegetable yields, scenario 3 would produce more food in terms of protein, calories and lysine.

Comparison of technology and best practice adoption in the three scenarios

In this section we compare the results for scenario 1+SRI, scenario 2+CFR, and scenario 3+ CFR+high

Table 4: Ranking of scenarios with and without training, best practice and technology adoption

Scenarios	Protein production		Calorie production		Lysine production	
	No adaptation	Training and technology adaptation	No adaptation	Training and technology adaptation	No adaptation	Training and technology adaptation
Scenario 1	2	3	1	1	2	3
Scenario 2	3	2	3	3	3	2
Scenario 3	1	1	2	2	1	1

vegetable yield. Projected annual production of protein and lysine in the potential area is highest in scenario 3: protein production is about 102,321 tonnes higher than in scenario 1 and about 21,866 tonnes higher than in scenario 2; lysine production is about 13,175 tonnes higher than in scenario 1 and about 1,030 tonnes higher than in scenario 2. Scenario 3 produces about 289 million kcals/year more than scenario 2 but about 2,367 million kcals/year less than scenario 1.

This study cannot compare water and energy requirements between the three scenarios with and without training and new technology adoption because such data is not available. However, the study does show that SRI adoption in scenario 1 can help reduce water use by up to 50 percent, and that SRI adoption in scenarios 2 and 3 can help conserve water and energy because this method reduces flooding in the wet season and saves water in the dry season.

Conclusion

Comparison between the three scenarios with and without support, training and best practice/technology adoption shows that: (1) projected protein production would be highest in scenario 3 both with and without training/technology adoption, while scenario 1 would drop to third and scenario 2 rise to second ranking; (2) the ranking for projected calorie production would remain unchanged, with scenario 1 ranked first followed by scenario 3; and (3) projected lysine production would be highest in scenario 3 with and without training/technology adoption, while scenario 2 would rise to second and scenario 1 drop to third ranking. Overall, scenario 3 has the highest potential for improving food production in terms of protein, calories and lysine in the potential area.

Different future agricultural development scenarios/policies have different implications. If the primary objectives are generating export income from rice and increasing calorific supply, these are maximised by scenario 1 – double rice cropping. If the primary objectives are to maximise profits for farmers and improve the supply of more nutritious foods (to reduce child stunting, for instance) then scenario 3 (rice - fish - vegetables) is best. In the future, with upstream dam development and climate change, water supply is likely to become less reliable. In this situation, scenario 1, which requires the most water, is most risky, whereas scenario 3 is moderately risky. The major drawback of scenario 3 is that it requires much more energy than the other two scenarios.

This research has outlined the costs and benefits of three different options for agricultural development in Cambodia. CDRI stands ready to support Cambodian agencies who wish to better understand these options to enhance governmental policies and on-ground programs.

References

Abrams, Julian Hilton. 2015. *Climate Resilient Irrigation Training: Promoting Climate Resilient Water Management and Agriculture Practice in Rural Cambodia.* Phnom Penh: MAFF Project Support Unit.

Anthofer, Jürgen. 2004. An Evaluation of the System of Rice Intensification in Cambodia. Report to the German Agency for Development Cooperation (GTZ). Phnom Penh.

Brooks, Alan, and Celine Sieu. 2016. The Potential of Community Fish Refuges (CFRs) in Rice Field Agro-ecosystems for Improving Food and Nutrition Security in the Tonle Sap Region. Penang, Malaysia: WorldFish

Bühler, Dorothee, Ulrike Grote, Rebecca Hartje, Bopha Ker, Do Truong Lam, Loc Duc Nguyen, Trung Thanh Nguyen and Kimsun Tong. 2015. *Rural Livelihood Strategies in Cambodia: Evidence from a Household Survey in Stung Treng.* Working Paper 137. Bonn: Center for Development Research, University of Bonn.

Canakci, M., M. Topakci, I. Akinci and A. Ozmerzi. 2005. "Energy Use Pattern of Some Field Crops and Vegetable Production: Case Study for Antalya Region, Turkey." *Energy Conversion and Management* 46(4), 655-666.

FAO (Food and Agriculture Organization). 1953. *Food Composition Tables for International Use.* 2nd edition. www.fao.org/docrep/x555 7e/x5557e00.htm.

FAO. 2001. *Food Balance Sheets: A Handbook.* www.fao.org/3/a-x9892e.pdf.

FAOSTAT. 2016. "Food and Agriculture Data." http://faostat3.fao.org/home/E.

Gregory, R., H. Guttman and T. Kekputhearith. 1996. *Poor in All but Fish: A Study of the Collection* *of Rice Field Foods from Three Villages in Svay Theap District, Svay Rieng*. AIT Aqua Outreach (Cambodia) Working Paper(4). Bangkok: Asian Institute of Technology.

Guttman, H. 1999. "Rice-field Fisheries — A Resource for Cambodia." AIT Aqua Outreach. Unpublished Paper.

Hortle, K., R.Troeung and S. Lieng. 2008. Yield and Value of the Wild Fishery of Rice Fields in Battambang Province, Near the Tonle Sap Lake, Cambodia. MRC Technical Paper No. 18. Vientiane: Mekong River Commission.

IRRA. 2010. Crop Area Map of Cambodia in 2010.

Islam, A.K.M.S., M.M. Hossain, R.I. Sarker, M.A. Saleque, M.A. Rahman, M.E. Haque and R.W. Bell. 2011. "Energy Utilization in Unpuddled Transplanting of Wet Season Rice." In *Proceedings of the 5th World Congress on Conservation Agriculture*, 133-136, 26-29 September, Brisbane, Australia.

MAFF (Ministry of Agriculture, Forestry and Fisheries). 2015. *Agricultural Sector Strategic Development Plan 2014-2018*. Phnom Penh: MAFF.

MAFF. 2016. *Annual Report for Agriculture Forestry and Fisheries 2015-2016*. Phnom Penh: MAFF.

McKenney, Bruce, and Prom Tola. 2002. *Natural Resources and Rural Livelihoods in Cambodia: A Baseline Assessment*. Working Paper No. 23. Phnom Penh: CDRI.

Nesbitt, Harry J., ed. 1997. *Rice Production in Cambodia*. Manilla: International Rice Research Institute.

Nurhasan, Mulia, Hanne K. Maehre, Marian Kjellevold Malde, Svein K. Stormo, Matthias Halwart, David James and Edel O. Elvevoll. 2010. "Nutritional Composition of Aquatic Species in Laotian Rice Field Ecosystems." *Journal of Food Composition and Analysis* 23:205-213.

ODC (Open Development Cambodia). 2015. Rice Ecosystem Map for Cambodia. https://opendevelopmentcambodia.net/layers/rice-ecosystem-map-for-cambodia/.

ODC. 2016. Soil Fertility of Cambodia. https://opendevelopmentcambodia.net/layers/soil-fertility-map-.

Pittock, Jamie, David Dumaresq and Stuart Orr. 2015. "The Mekong River: Trading Off Hydropower, Fish and Food." *Regional Environmental Change:*1-11 doi: 10.1007/s 10113-017-1175-8.

RGC (Royal Government of Cambodia). 2015. *National Strategic Development Plan 2014-2018*. Phnom Penh: Council for the Development of Cambodia.

Ros Bansok, Chhim Chhun and Nang Phirun. 2011. *Agricultural Development and Climate Change: The Case of Cambodia*. Working Paper Series No. 65. Phnom Penh: CDRI.

Tech Chey. 2004. "Ecological System of Rice Intensification (SRI) Impact Assessment. CEDAC Field Document." Phnom Penh: Cambodian Center for Agricultural Studies and Development.

Theng Vuthy, Khiev Pirom and Phon Dary. 2014. *Development of the Fertiliser Industry in Cambodia: Structure of the Market, Challenges in the Demand and Supply Sides, and the Way Forward*. Working Paper Series No. 91. Phnom Penh: CDRI.

Thouk N. 2009. "Community Fish Refuge Husbandry in Lowland Agriculture Ecosystem." Doctoral thesis, Build Bright University, Phnom Penh.

Troeung, R., Aun, S., Lieng, S., Deap, L. and N. van Zalinge. 2003. "A Comparison of Fish Yields and Species Composition between One Fishing Lot in Battambang Province and Two Fishing Lots in Prey Veng Province." *MRC Conference Series* 4: 9-16.

Uphoff, Norman. 2006. "The System of Rice Intensification (SRI) as a Methodology for Reducing Water Requirements in Irrigated Rice Production." Paper presented at the International Dialogue on Rice and Water: Exploring Options for Food Security and Sustainable Environments, Los Baños, Philippines, 7-8 March. http://citeseerx.ist.psu.edu/ viewdoc/download?doi=10.1.1.512.7440&rep=rep1&type=pdf.

World Bank. 2015. *Cambodian Agriculture in Transition: Opportunities and Risks*. Washington, DC: World Bank.