Synergies and Trade-offs with Intensification of Rice and Livestock Production in Cambodia

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ACRONYMS

CMDG	Cambodia Millennium Development Goals
CSES	Cambodia Socio-Economic Survey
ELC	Economic land concession
FAO	Food and Agriculture Organization of the United Nations
FSN	Food security and nutrition
GDP	Gross domestic product
LASED	Land Allocation for Social and Economic Development
MAFF	Ministry of Agriculture, Forestry and Fisheries
OAAs	Other aquatic animals
RGC	Royal Government of Cambodia
RS	Rectangular Strategy
SPS	Sanitary and phyto-sanitary

GLOSSARY

Floating rice	Floating rice is cultivated around the Tonle Sap Lake and beside the Mekong and Basak River in the provinces of Kompong Thom, Banteay Meanchey and Battambang. Smaller areas of cultivation can be found in Siem Reap, Pursat, Kandal and Takeo. In this system, rice is grown in water up to four metres deep.
Cash crop	Any crop that is sold off the farm.
Deciduous forest	Forest composed primarily of broad-leaved trees that shed their leaves during one season. Deciduous forest is found in three middle-latitude regions with a temperate climate characterised by a winter season and year-round precipitation: eastern North America, western Eurasia, and north-eastern Asia.
Broadleaved evergreen forest	Forest in humid subtropical area composed of evergreen broad-leaved trees.

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EXECUTIVE SUMMARY

This study examined the benefits, risks and costs of changing food production from flood recession to regulated, irrigated agriculture in Cambodia, considering food production, land, water, energy and livelihoods. Methods were used in this study include food supply calculation, nutritional supply estimation, potential production area projection, water use estimation, energy consumption estimation. Three scenarios were designed to compare current food supply (in term of protein, calories and lysine), food production projection (in term of protein, calories and lysine), water use and energy consumption in the potential production area under three farming systems. Scenario 1 was double rice cropping (wet-reason rice and dry-season rice). Scenario 2 was wet-season rice / ricefield fish / OAA / bovines. Scenario 3 was wet-season rice / ricefield fish / OAA / vegetables.

Current food supply per hectare in the three scenarios: In Scenario 1, dry-season and wet-season rice crops were grown. Total annual rice crops protein of about 0.12 t/ha, about 5,880 kcals/ha and lysine of about 0.005 t/ha. In Scenario 2, rice, fish and OAA were harvested from rice field in the wet season. After harvest, the rice areas were used for raising bovines. Results indicates total annual food supply of protein of about 0.1 t/ha, calories of about 3,256 kcals/ha and lysine of about 0.006 t/ha. In Scenario 3, rice, fish and OAA were harvested in the wet season. After harvest, the rice areas were used for growing vegetables. The results showed that total annual food supply per hectare yields protein of about 0.19 t/ha, about 4,469 kcals/ha and lysine of about 0.01 to/ha.

Projections for food products for the three scenarios: The current irrigated single rice crop areas that had potential for irrigated double rice cropping (125,724 ha). For scenario 1, if the irrigated single rice crop areas (125,724 ha) were converted to irrigated double rice cropping, the annual production of protein, calories and lysine from rice would double: protein would reached about 29.475 t/year, lysine about 900 t/year and calories about 1,403 million/year. For scenario 2, rice farming in the irrigated area (125,724 ha) was limited to a single wet-season crop grown in an integrated rice-fishery system that allows for the production of fish and OAA in the same rice field. After harvest, this area was used for raising cattle. Total production of protein was about 15,363 t/year, calories about 559 million/year and lysine about 729 t/year. For scenario 3, as in scenario 2, rice in the irrigated area (125,724 ha) was limited to a single wet-season crop grown in an integrated rice-fishery system. After harvest, this area was used for growing vegetables. Total production of protein will reach about 29,898 t/year, calories about 751 million/year and lysine about 1,398 t/year.

Water use and energy use projection: For scenario 1, about 3,017 MCM of water will be needed for irrigated double rice. The farming system in scenario 2 will need about 1,508 MCM of water, and that in scenario 3 will require about 2,451 MCM. Irrigated double rice cropping in scenario 1 will require about 6,726 million MJ of energy. Agricultural production in scenario 2 will need about 3,363 million MJ of energy and in scenario 3 about 11,058 million MJ.

The benefits of scenario 1 included increased income from rice export, highest current food supply and highest food product projection of calories, and second highest current food supply and food supply projection of protein and second highest food supply projection of lysine. However, this scenario had the highest water costs and the second highest costs for energy, fertiliser, insecticide and labour. The significant amounts of water needed make production in scenario 1 the most risky, not to mention the negative effects of hydropower dams and climate change on water quantity and quality. Irrigation system or water supply costs would need to be considered. Although ranked second for energy consumption, support would be needed to manage the implications of high-energy agriculture.

Double rice crops required a higher rate of fertilisation than single rice crops, though lower than that for wet-season rice and vegetables. Long-term use of inorganic fertilisers could alter soil chemistry and biology, and harm the soil ecosystem. Increased inorganic fertiliser used heightens these risks but less so than in scenario 3. Similarly, scenario 1 used pesticide in second ranked in the potential area. Pesticide hazards included direct impacts on human health, food safety, environmental health, surface, soil fertility, air, soil and water quality, and non-target vegetation and organisms. Methane and nitrous oxide emissions will increase under double paddy. With fertilisation, the global warming potential of scenario 1 will be higher than scenario 3, but without fertilisation it will be the same. If farmers adopt system of rice intensification (SRI) methods, scenario 1 could produce more food (protein, calories and lysine) using 50 percent less water, while simultaneously reducing energy and inorganic fertiliser inputs and improving soil quality and water retention.

Scenario 2 stood to provide the second highest current food supply of lysine but the lowest current food supply and food production projection of protein and calories. This scenario had the lowest costs. The risks to production were the same as for scenario 1 but the level of risk was lower than for scenario 1 because it used the lowest inputs of water, energy, fertiliser and insecticide. If farmers adopt community fish refuges, projected food production (protein, calories and lysine) in the potential area would increase.

Scenario 3 will provide the highest current food supply and food product projection of protein and lysine, and the second highest current food supply and food product projection of calories. Importantly, the four sources of protein could help reduce the incidence of stunting and underweight in Cambodia. The gross margin of vegetables was higher than that of wet-season and dry-season rice, and vegetable production would help meet domestic demand for fresh produce. However, energy, fertiliser, insecticide and labour costs were the highest, and water costs the second highest, among the three scenarios. Water use was high and poses the main risk to production, as in scenario 1, though the level of risk is lower. Energy consumption was the highest among the scenarios. This would require attention to energy supply in the potential area. The risks from fertiliser and insecticide use were the same as for scenarios 1 and 2, but the level of risk was higher because higher rates of fertiliser and insecticide were applied to wet-season paddy and vegetables. The risk associated with increases in methane and nitrous oxide emissions was the same as for scenarios 1 and 2; the level of risk was higher with inorganic fertiliser application, but the same without them. If farmers were to adopt community fish refuges (CFRs) and attain high vegetable yields, scenario 3 would produce more food in terms of protein, calories and lysine.

Comparison between the three scenarios with and without training and best practice/technology adoption (CFRs, SRI, high vegetable yield) showed that: (1) projected protein production would be highest in scenario 3 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. Further, the study showed that SRI adoption in scenario 1 helped reduce water use by 50 percent, and CFR adoption in scenarios 2 and 3 saves water and energy.

Overall, scenario 3 had the highest potential for improving food production in terms of protein, calories and lysine in the potential area.

1. INTRODUCTION

1.1 Overview of Cambodian agriculture

Cambodia has a tropical monsoon climate of two seasons, a rainy season (mid-May to mid-September/early October) and a dry season (early November to early May) (Bansok, Chhun, and Phirun 2011). Agriculture is a high priority for the government's national development agenda. The government expects agricultural development to reduce poverty by improving food security and increasing household incomes and employment. Agricultural development also contributes to economic growth and macroeconomic stability (MAFF 2015a). The main agricultural activities are rice, subsidiary and industrial crops, poultry and livestock. There are four major ecosystems for cultivating rice in Cambodia: rain-fed upland rice, rain-fed lowland rice, dry season irrigated rice and floating and recession rice (Bansok, Chhun, and Phirun 2011). In 2014, the paddy area was 2.96 million ha. Farmers also cultivate cash crops—beans, cassava, sesame, maize—and raise poultry (chickens, ducks) and livestock to supplement subsistence or earn income (MAFF 2015a).

The wet season rice crop may be delayed by changing rainfall patterns. This change might affect rice and other crops. Furthermore, a short drought occurs between late July and early August during the wet season. Crops are likely to be significantly affected if this drought is extended. Farmers report that in recent years their crops were damaged. This impact is related to climate issues: flood, drought and changing rainfall patterns (Bansok, Chhun, and Phirun 2011).

The government has invested in irrigation infrastructure. The Strategy for Agriculture and Water set targets of increasing irrigated crop lands by 100,000 hectares between 2010 and 2013 and reducing the "incidence of drought- or flood-affected farmland" by 20 percent. As a result, in the five years 2009-2013, the irrigation system expanded to provide water for an additional 387,907 ha of agricultural land. The total area able to be irrigated in 2013 was 1,485,670 ha (1,050,135 ha in the rainy season and 435,535 ha in the dry season). The government has committed to further enhancing water resource management and improving irrigation infrastructure; developing a legal framework, institutions and human resources related to water resources; repairing and maintaining irrigation systems; and encouraging integration between irrigation, hydropower and transportation projects (RGC 2015).

1.2 Importance of rice production and fish catch

1.2.1 Rice production

Rice growing is the principal basis of food security and an important source of employment and income for Cambodians (Bühler et al. 2015; McKenney and Tola 2002). The national food requirement was 2,178,050 tonnes of milled rice in 2015. From paddy of 9,324,416 tons, 13 percent or 1,212,177 tons went for seed reserve and post-harvest losses. Therefore, the paddy available for consumption was 8,112,239 tons or about 5,191,833 tons of milled rice, so (less 2,178,050 tonnes consumed nationally) the surplus was 3,013,783 tons. Rice production also provided a lot of employment for Cambodians (MAFF 2015b). The gross value of paddy rice production was about USD2.49 billion in 2012, increasing to USD2.55 billion in 2013 (FAO 2016b). Farmers sell surplus rice, and this income may be enough to meet production costs including fertilisers, pesticides and hired labour (McKenney and Tola 2002).

1.2.2 Fishing in rural livelihoods

Fishing is a main support to food security, income and employment in rural areas (McKenney and Tola 2002).

Fish consumption and food security

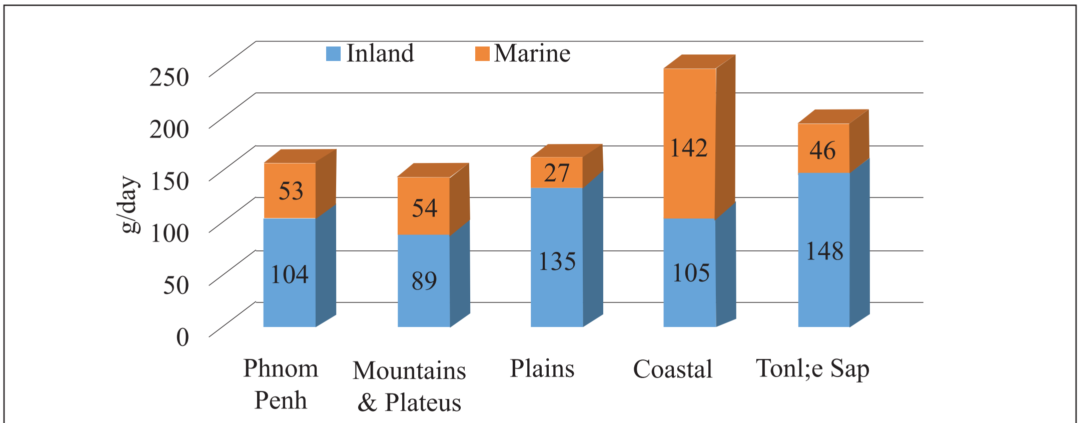
Fish is a traditional rich source of protein in the Cambodian diet. The inland fisheries are the main support of Cambodia's food security; they are the most productive in the region and fourth most productive in the world (Van Zalinge et al. 2000). According to Table 1, the average fish and aquatic products consumption of Cambodians is 63 kg/person/year. The average of inland fish consumption is 40.3 kg/person/year and marine fish consumption 16.2 kg/person/year. The average annual per capita consumption of inland capture resources is 44.3 kg/person/year (IFReDI 2012). The fish consumption results of the IFReDI study are similar to those of previous studies. For instance, Ahmed M. (1998) showed that the Cambodian average consumption of fresh inland fish was 43.5 kg/person/year. However, another study found 36.8 kg/person/year (Hortle 2007). The highest marine and freshwater consumption rates were found in or near fishing villages (Ahmed M. 1998). Fish consumption in the Tonle Sap and coastal areas was higher than in other areas (Figure 1). Consumption of inland fish and other aquatic animals was higher than marine fish consumption in all areas except for the coastal zone (IFReDI 2013).

Table 1: Average annual fish consumption of fish per person and per year in Cambodia, 2011

			Annual intake in Fish and Fish Products (kg/person/year)	
Inland capture resources	Inland fish	Floodplain residents	18.8	40.3
		Long-distance migrants	15.5	
		Short-distance migrants	6	
	Other inland aquatic animals		3.9	3.9
Marine capture resources	Marine fish		16.2	17.4
	Other marine aquatic animals		1.1	
Aquaculture			1.3	1.3
Grand total			*63*	

Source: (IFReDI 2012)

Figure 1: Average daily per capita fish consumption disaggregated by inland and marine fish



Source: (IFReDI 2012)

Income Generation and Employment

Fisheries provide employment and livelihoods for many people, including through capture, culture, processing, distribution and trade. About 42 percent of households in Cambodia are engaged in fishing activities: in the plateau/mountain zone 55 percent, Tonle Sap zone 51 percent, coastal zone 47 percent, plains zone 42 percent and Phnom Penh 1 percent. In addition, 2 percent of all households were involved in aquaculture activities in 2014 (NIS 2015b).

The combination of agriculture and fishing gives employment to many people in rural areas, but most farmers say that fishing is a secondary occupation. For instance, Ahmed M. (1998) studied representatives of the 2.4 million people who live along main water bodies or in inundated areas and found that 36 percent of household heads were actively engaged in fishing; for 9.3 percent this was the primary employment, for 20.3 percent secondary employment and 6.3 percent tertiary employment. These findings cannot be generalised to the entire country. According to the (FiA 2011, 2) "The fisheries sector has for many years contributed significantly to the employment and livelihoods of the poor. Cambodia's fisheries provide full-time, part-time and seasonal employment for up to 6 million people".

1.3 Current Cambodian agricultural production

1.3.1 Cultivated area, yield and production of rice

The total area of rice farming has increased in the last 10 years. The cultivated paddy crop increased from 3.052 million ha in 2013 to 3.055 million ha in 2014 (Figure 2). Dry season rice cultivation increased from 0.485 million to 0.491 million ha. However, it decreased from 2.568 to 2.565 million ha in the rainy season (MAFF 2015b).

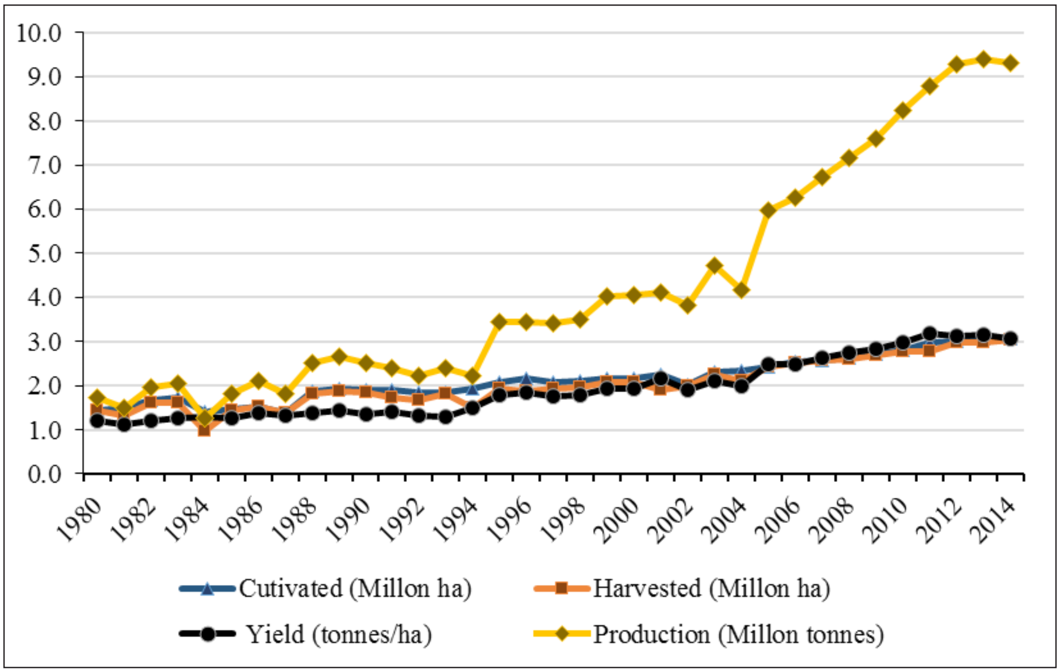
Between 2004 and 2014, the average rice yield increased from 2.0 tons/ha to 3.1 tons/ha. The yield reached 3.2 tons/ha in 2011 and in 2013 but was 3.1 tons/ha in 2012 and 2014 (Figure 2). The average yield in 2014 hides seasonal differences. Yield in the rainy season decreased from 2.9 to 2.8 tons/ha, but it increased from 4.38 to 4.44 tons/ha in the dry season (MAFF 2015b). Dry season rice cultivation is more productive, but relies on irrigation, using of fertilizers, higher-yield seeds and higher commitments to watch over (Yu and Fan 2011).

Comparing 2014 to 2013, the area of cultivated rice increased 2 percent, but the yield decreased by 2.67 percent (Figure 2). Therefore, rice production decreased from 9.39 million tons in 2013 to 9.32 million tons in 2014. According to MAFF (2015b), this decrease was due to climate change, especially drought. The area destroyed by drought was about 20,286 ha, the highest amount in five years (the destroyed area was only 178 ha in 2013) (MAFF 2015b). However, rice production increased from 2004 to 2013 (Figure 2). Table 2 lists reasons for the increase.

Table 2: Reasons for increasing rice production during 2004-2013

Increase period	Reasons
2013 increased 23.78% over 2009	Increasing price provided an incentive (MAFF 2015a).
2003-2012	Land expansion contributed 42% of the increase in rice production (World Bank 2015).
1994-2009	Farmers extended cultivated area. Planting of modern varieties increased (Bansok, Chhun, and Phirun 2011).

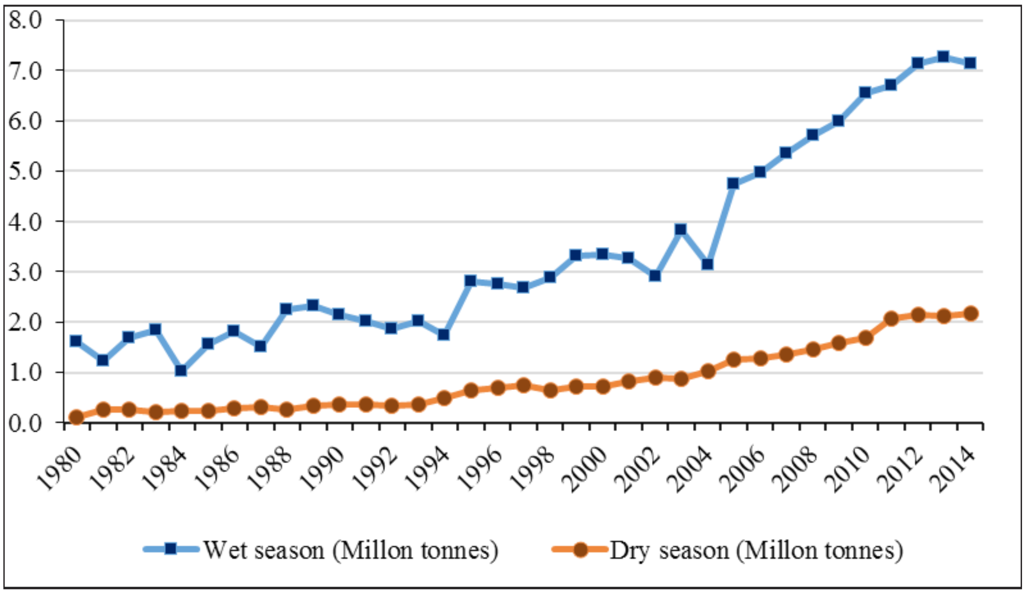
Figure 2: Rice cultivation, 1980-2014



Source: (MAFF 2015b)

Wet season rice in Cambodia mostly relies on rainfall and water supply from irrigation (Bansok et al 2011). Wet season rice production is higher than dry season production (MAFF 2015b). Wet season rice production increased every year from 2004 to 2014, except for 2014, when it decreased to 7.14 million tons from 7.27 million tons in 2013. Dry season rice production increased from 1.04 million tons in 2004 to 2.18 million tons in 2014 because of an expanding cultivated area and yield improvement. Dry season rice production increased every year for 10 years, excluding 2013 (Figure 3).

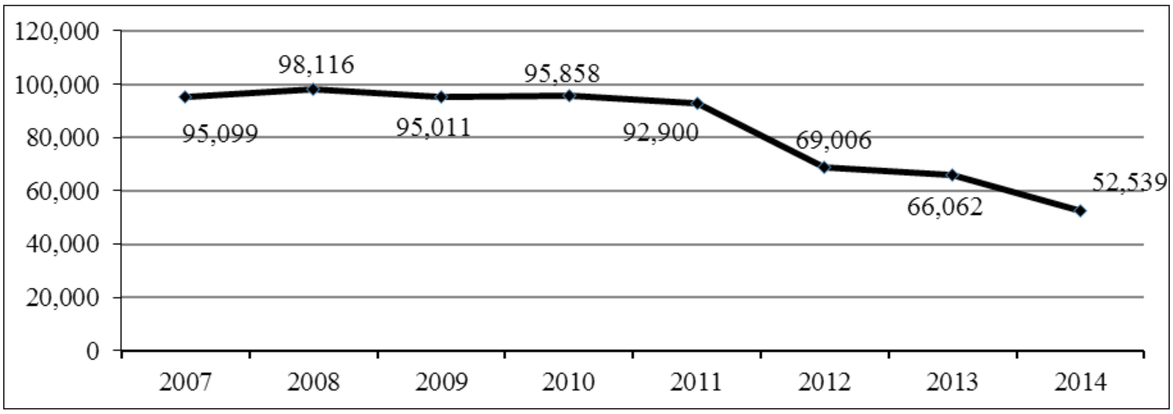
Figure 3: Rice production by season, 1980-2014



Source: (MAFF 2015b)

Floating rice production increased in 2008 (98,116 tons) but decreased during the next six years (2009-2014). In 2014, production of floating rice was only 52,539 tons (Figure 4). Half of the decrease was because of changing natural flooding due to the existing and planned construction of hydropower dams in the basin (Räsänen et al. 2012). The area of dry season cultivation increased while the area of floating rice decreased (MAFF 2015b).

Figure 4: Floating rice production (tonnes), 2007-2014

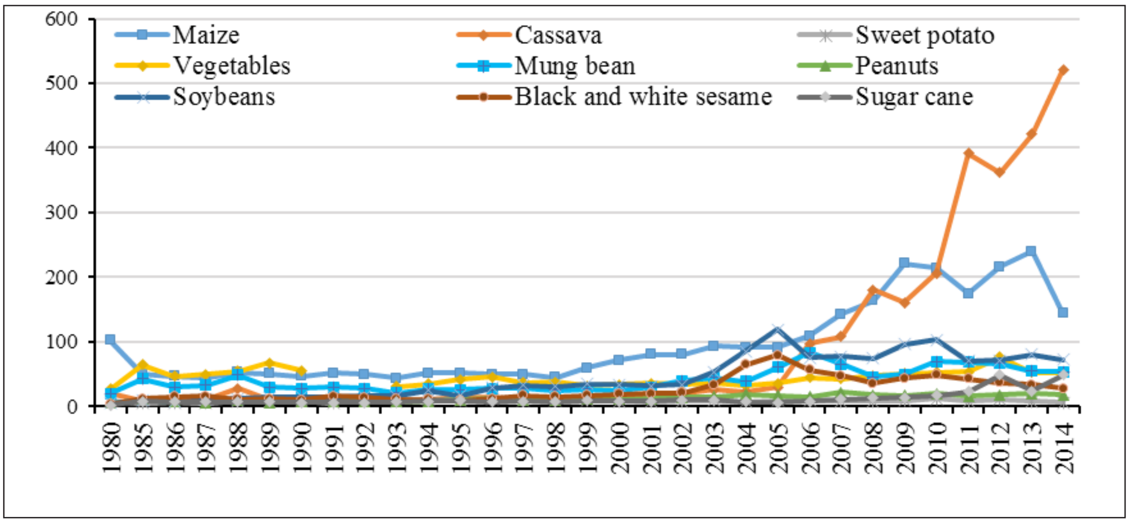


Source: (MAFF 2015b)

1.3.2 Other major cash crops

Cash crops are regarded as the main source of income for improving livelihoods and savings. They are often cultivated in the highlands because the soil in this area is rich and fertile (Bansok et al. 2011). The cultivated area of cassava increased from 22,749 ha in 2004 to 521,459 ha in 2014, 23 times the earlier figure. The cultivated area of maize increased from 91,203 ha in 2004 to 239,748 ha in 2013; it decreased to 143,517 ha in 2014. The cultivated area of soybeans decreased due to low market demand (Figure 5). The cultivated area of non-rice crops increased more than the rice farming area. Rice farming decreased from 86 percent of total farming area in 2002 to 74 percent in 2011. Farmers diversified because of higher rates of profitability, the existence of a stable market and for cultural reasons (World Bank 2015).

Figure 5: Cultivated Area ('000 ha) of Major Crops, 1980-2014

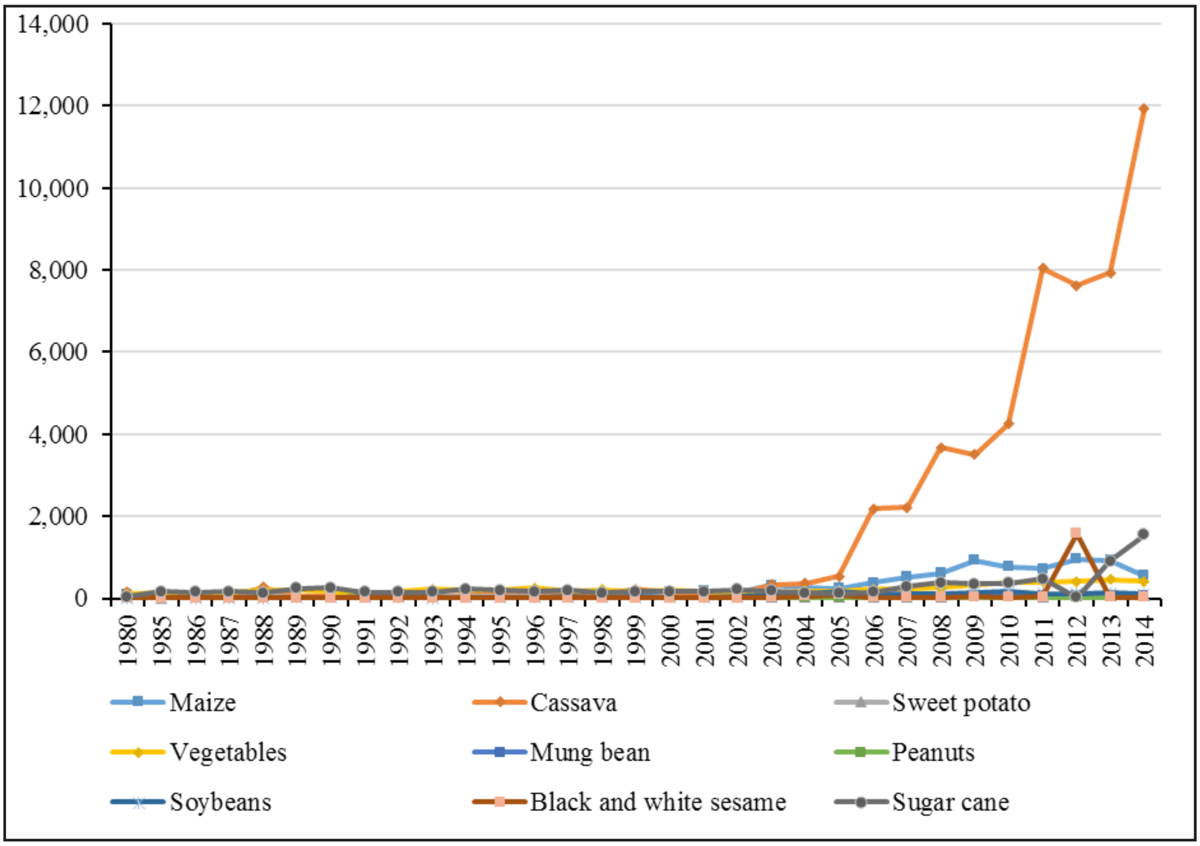


Source: (MAFF 2015b)

Crops must be connected to markets. Increased production of a single crop results in the relative decrease of other crops. For instance, farmers expanded cultivation of cassava. As a result, the production of other crops decreased. The prices of these crops can rise slightly because of the limitation of production and supply. The prices of these crops are regularly determined by middlemen during cultivation time, but farmers obtain lower prices at harvest time (Bansok, Chhun, and Phirun 2011).

The cultivated areas of subsidiary and industrial crops reached 941,000 ha in 2013, an increase of 40 percent over 2009. This was largely due to cassava and maize production (MAFF 2015a). Cassava production increased from 330,640 tons in 2003 to 11,943,204 tons in 2014. However, maize production decreased in 2014 to only 549,607 tons, compared to 950,909 tons in 2012 and 926,846 tons in 2013 as farmers switched to cassava (Figure 6).

Figure 6: Production ('000 tons) of major crops, 1980-2014



Source: (MAFF 2015b)

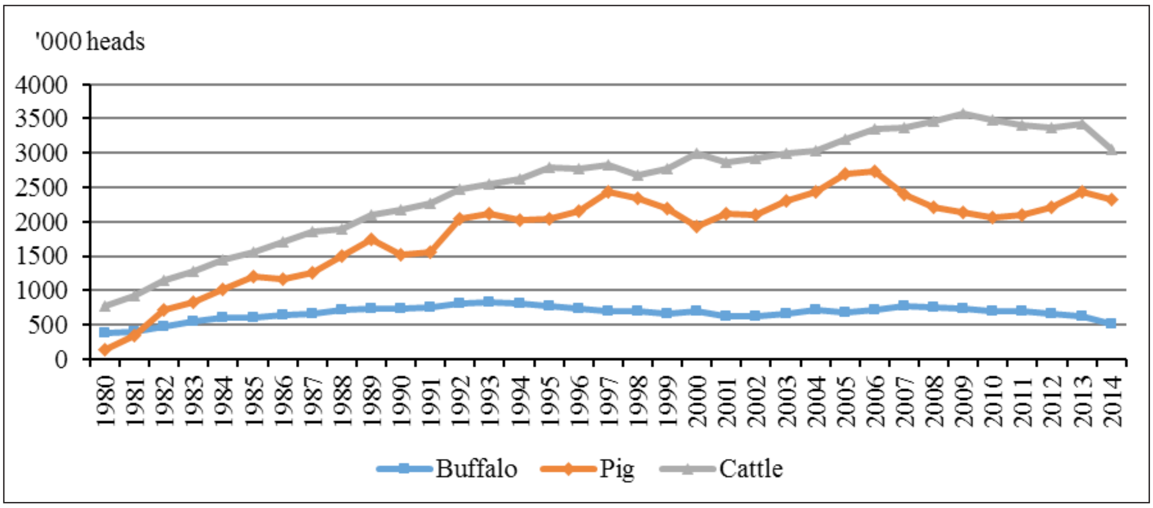
1.3.3 Livestock and poultry

Most farmers benefit from livestock. However, there are six major problems associated with livestock in Cambodia: poor nutrition; high mortality and morbidity rates; lack of disease/ infection control; weak veterinary services; lack of animal vaccines and medicines; and small animal size because of poor breeding practices (ADB 2008).

Cattle and buffaloes: Cattle and buffaloes are raised in rice-cultivating zones. Most buffaloes are found in low-lying areas around the Great Lake and in Prey Veng and Svay Rieng provinces. Buffaloes tend to perform better than cattle in heavy labour. Rice straw is an important feed for cattle and buffaloes, particularly when grass is restricted (McKenney and Tola 2002). From 2009 to 2013, cattle production declined from 3.6 million to 3.4 million head, about

4.20 percent. Buffalo production declined about 16.4 percent, from 740,000 head in 2009 to 619,000 in 2013. The decreases occurred because of the decreasing use of draught animals and the increasing use of tractors and machinery (70 percent of paddy area was ploughed by machines). Cattle feeding has also been constrained by the lack of labour in rural areas (due to migration) and the difficulty of finding water and grass. While decreasing the use of draught animals, farmers have changed to fattening cattle. Private sector investment in fattening cattle has increased (MAFF 2015a). In 2014, buffalo and cattle production continued to decline, buffaloes to 518,123 head and cattle to 3,053,481 head (Figure 7).

Figure 7: Livestock ('000 head), 1980-2014

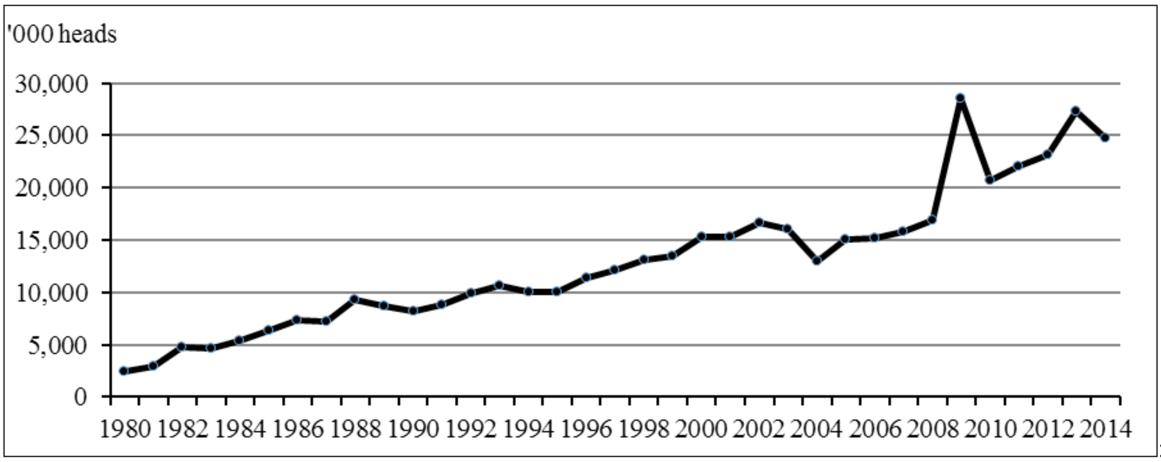


Source: (MAFF 2015b)

Pigs: Farmers raise pigs throughout the country. The highest numbers of pigs per household are found in Kampot, Takeo and especially Svay Rieng province (from which they can be exported to Vietnam). The important food for pigs is rice bran (from local paddy rice), which farmers can purchase from local rice millers. The number and profitability of pigs are based on the quantity, quality and price of rice bran in the area. From 1997 to 2000, pig numbers decreased from 2.4 to 1.9 million head; the causes of the decrease are not stated clearly. The mature weight and meat quality of pigs depend on the quality of the breed. Thus the decrease in pig numbers does not necessarily mean a decrease in the total value of pig sales if farmers have been changing to pigs of a higher quality breed (McKenney and Tola 2002). Pig production increased by 15 percent to 2.40 million head in 2013 because of the establishment of medium and large animal production farms. Animal feed factories have been established, and farmers have become aware of using feed and fodder effectively and participated in producing animal feed and pastures (MAFF 2015a). However, feed and animal medicines are still relatively expensive. In 2014, pig production decreased to 2.3 million head (Figure 8).

Poultry: Chickens and ducks are the most popular poultry for Cambodian farmers. Most village chickens are raised around the home, where they scavenge or sometimes have rice scattered to them. Most ducks are raised near lakes and ponds, especially during the dry season. Ducks also scavenge in rice paddies, lakes and ponds. Intensively raised chickens and ducks are increasing, particularly around Phnom Penh. According to MAFF data, poultry numbers increased over the past decade, but the numbers of chickens and ducks are difficult to record accurately (McKenney and Tola 2002). Chicken and duck production increased to 27.32 million, in 2013. In 2013 alone, production increased by 18.26 percent over 2012 (MAFF 2015a). However, poultry number decreased to 24.81 million in 2014 (Figure 8).

Figure 8: Poultry ('000 head), 1980-2014

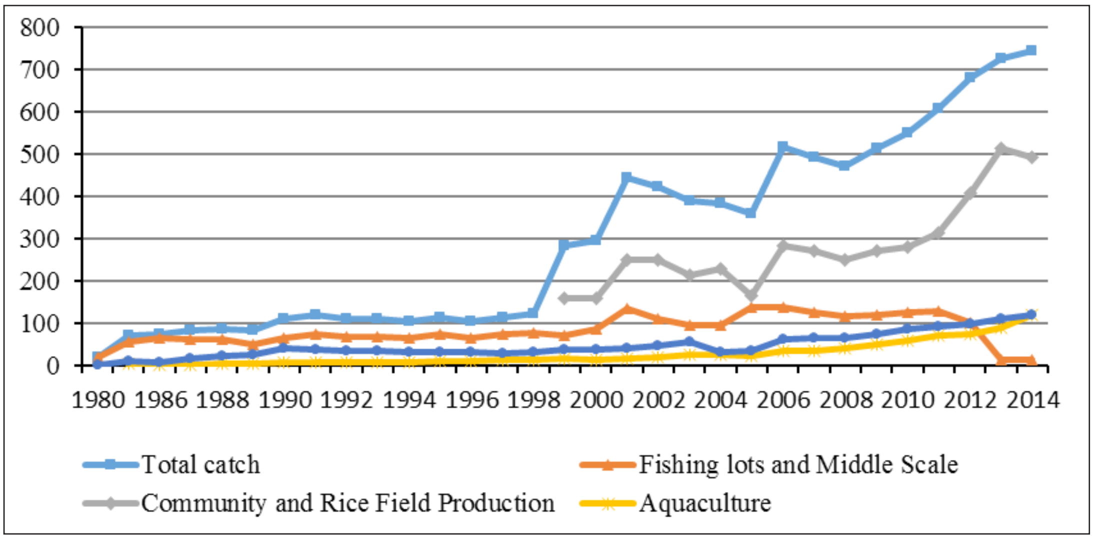


Source: (MAFF 2015b)

1.3.4 Fisheries

Cambodia possesses one of the largest and most diverse fisheries in the world, with over 30 percent of the country comprising either permanent or seasonal wetlands. Fish provide protein and are particularly vital for food security and income for the poorest people (MAFF 2015a). During 2009 to 2014, total annual fish production increased because of increasing production of community and rice field fish, aquaculture and marine catch. It increased from 728,000 tons in 2013 to 745,310 tons in 2014. Community and rice field fish production increased from 229,500 tons in 2004 to 515,000 tons in 2013, but decreased to 492,720 tons in 2014. Aquaculture increased from 25,760 tons in 2004 to 120,055 tons in 2014. Marine fish production also increased, from 32,600 tons in 2004 to 120,250 tons in 2014. However, due to changes in government regulations, fishing lot and middle scale production declined during the decade, especially in 2013 and 2014, from 95,000 tons in 2004 to 13,000 tons in 2013 and 12,285 tons in 2014 (Figure 9).

Figure 9: Annual Fish Catch by Province ('000 tonnes), 1980-2014



Source: (MAFF 2015b)

1.4 Mekong floodplain

The Mekong River is ranked as the 10th largest river in the world; its annual discharge is 475 km^3 (Finlayson and Spiers 1999). Its length (4350 km) is the 12th largest globally, and its drainage area is 21st (795,000 km^2) (Kingston, Thompson, and Kite 2011). Nineteen percent of the total Mekong River basin is located in Cambodia (MRC 1998). During the flood season, an extensive wetland habitat is generated by Mekong and its tributaries. Thousands of square kilometres of floodplain forest and shrub land are temporarily submerged (McKenney and Tola 2002). From July to November can be considered as the Cambodian flood season (Douven, Goichot, and Verheij 2009), with annual flooding of up to 40,000 km^2 of lowland areas (MRC 2005). The peak discharges are generally in August and September, at a rate of approximately 45,000 m^3/s, and the lowest discharge is about 1500 m^3/s at Phnom Penh (Douven, Goichot, and Verheij 2009).

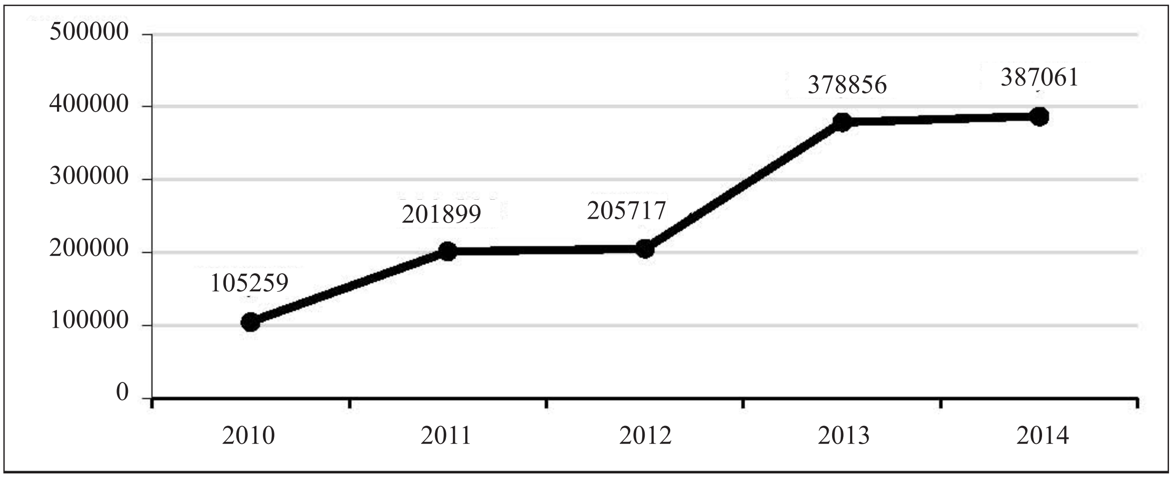
The Tonle Sap Lake is the largest freshwater lake in South-East Asia (Finlayson and Spiers 1999). The Tonle Sap is part of the Mekong basin wetland ecosystem, with a floodplain that extends over 15,000 km^2 during the wet season (MRC 2005; Dang et al. 2015). The linking between Tonle Sap Lake and Mekong River is provide great importance for Cambodia and the lower Mekong basin (Hortle, Troeung, and Lieng 2008; Nesbitt 1997). The Great Lake provides extremely important natural resources, especially for people living around it, and more than a million Cambodians depending on its natural resources. In June, the start of the wet season, the lake obtains water from the Mekong and becomes six times as large, growing from about 2500 km^2 in the dry season to about 15,000 km^2 during the wet season (Troeung et al. 2003; MRC 2005; Arias et al. 2012). The water volume varies from 1.5 to 70 km^3 and the maximum water depth of the lake increases from 1 to 9 m. The large variations in water level inundate some areas around the lake during the wet season (MRC 2005). Farming based on this phenomenon is the main economic activity in the Mekong floodplain (McKenney and Tola 2002; MOWRAM 2003; Arias et al. 2012). Rice farming occupies 90 percent of the total cultivated land area of Cambodia, concentrated on the floodplain of the Mekong and Tonle Sap Lake (Arias et al. 2012). In the dry season, farmers grow vegetables and other crops on fertile land along riverbanks. In upland areas, farmers usually grow rice and vegetables in the same field in the wet season (McKenney and Tola 2002). Irrigation systems are used in the central lowlands partly to control the water flow into and out of the floodplain and to direct water from the Mekong for crops (MOWRAM 2003).

The Mekong floodplain in Cambodia is threatened by current and future hydropower dams and other infrastructure development (ODC 2015; Dang et al. 2015). According to Cagauan, Branckaert, and Van Hove (2000) and Dang et al. (2015), dry season water levels have increased and flood levels have reduced due to upstream hydropower development. For instance, Kummu and Sarkkula (2008) found that the dry season water level of the Tonle Sap Lake has increased by 0.15–0.60 m because of upstream development on the Mekong. Based on various studies of the MRC, the maximum discharge may be changed in the future due to global climate change and large dam construction. These studies show that a maximum discharge is about 65,000 m^3/s and a minimum discharge is about 30,000 m^3/s (Douven, Goichot, and Verheij 2009). Flow changes could be harmful to the lake ecosystem (Kummu and Sarkkula 2008). This would have adverse impacts on the Cambodians who rely directly on the lake's natural resources (Kummu and Sarkkula 2008; Dang et al. 2015).

1.5 Cambodian agricultural exports

The Ministry of Agriculture, Forestry and Fisheries, in cooperation with other ministries and agencies, has succeeded in halving the time required to process export applications. It created a "one window service" for rice export processing. It issues certificates for sanitary and phyto-sanitary (SPS), fumigation, grading and quality, quantity and weight, and customs declaration (MAFF 2015a).

Figure 10: Rice export (tonnes), 2010-2014



Source: (GDA 2014)

In 2014, Cambodia issued 17,732 SPS certificates for 47 types of agricultural exports. Exports of rice increased from 105,259 tons in 2010 to 387,061 tons in 2014. Compared to 2013, they increased only 2.2 percent (8205 tons) (Figure 10). White rice (157,417 tons), aromatic rice (210, 594 tons) and steamed rice (19,050 tons) were exported to 59 countries in 2014. The top 10 countries were France (70,077 tons), Poland (55,938 tons), China (48,980 tons), Malaysia (48,120 tons), Netherlands (32,024 tons), Belgium (17,515 tons), Czech Republic (13,198 tons), United Kingdom (11,829 tons), Spain (11,728 tons), and Germany (11,502 tons) (GDA 2014) .

Some subsidiary and industrial crops are exported to China, Thailand, Vietnam, Japan, Taiwan and North Korea: sliced cassava, fresh manioc, cassava starch, cassava residue, sugar cane, soybeans, sesame, mung beans and mixed vegetables. Vegetables were exported to 16 countries (Table 3).

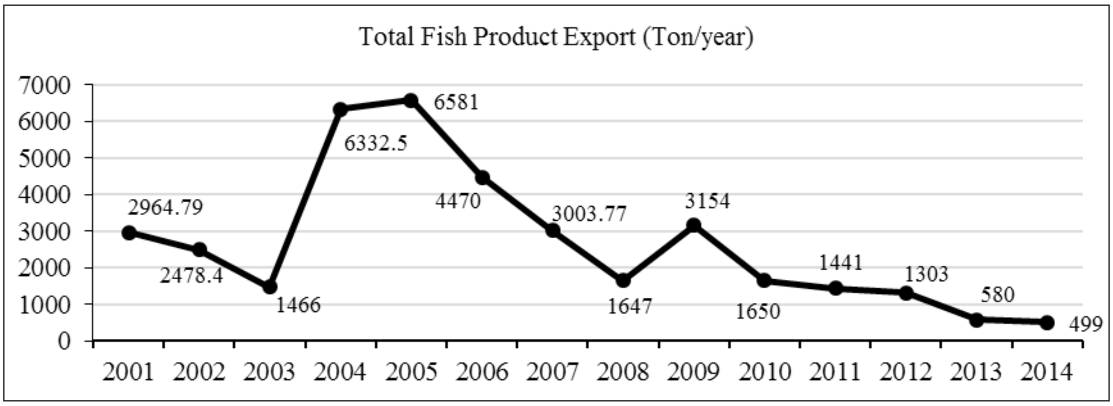
Freshwater fisheries exports are divided into three types. First, Cambodia exports chilled fish to Thailand via large trucks and cars. Second, live freshwater species and catfish fingerlings are exported to Vietnam via waterways, using cages pulled by large boats. Lastly, high-value live fish and some fish products are exported to Asian countries (Malaysia, Hong Kong, Singapore and China) and frozen fish, fish fillets and fishballs, and salted dried fish are exported to the USA, Australia, Japan and Taiwan by air. According to the fisheries export company KAMFIMEX, the USA and Australia are the most important markets for Cambodia's fisheries exports; second are China, Hong Kong, Singapore and Malaysia; third are Thailand and Vietnam (Rab et al. 2006). Fish product exports declined from 6332 tons in 2004 to 499 tons in 2014 (Figure11).

Table 3: Exports of subsidiary and industrial crops, 2014

Name	Quantity (Tonnes)	Destination
Cassava slice	1,419,141.94	China, Thailand, Vietnam
Fresh manioc	576,238.00	Vietnam, Thailand
Sugar cane	212,031.00	Vietnam, Thailand
Soybeans	128,940.00	Vietnam, Japan
Cassava Starch	15,325.40	China, Vietnam
Cassava residue	13,376.00	China
Sesame	11,661.05	Vietnam, China, Taiwan
Mung bean	9,100.00	Vietnam
Vegetables	1,260.50	16 countries
Mixed vegetables	325.84	North Korea

Source: (GDA 2014)

Figure 11: Total fish product exports, 2001-2014



Source: (MoC 2014)

1.6 Food and fodder/stock feed imports

Purchased feed for livestock and poultry was estimated to be 699,000 million riels (about USD174.75 million) in 2009. More feed is purchased in the Tonle Sap and plains zones (NIS 2015b). The value of residues, animal fodder and food industry wastes used as animal feed rose from USD6573 USD in 2004 to USD216,298 in 2014 (Table 4).

Table 4: Import value of residues, wastes of food industry, animal fodder 2004-2014 (USD)

Product label	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Animal feed preparations, NES	6,573	19,302	21,499	27,862	41,059	43,534	37,151	55,901	75,971	58,094	144,574
Soya bean oil cake and other solid residues	0	0	0	0	701	2,961	4,076	1,0641	19,379	17,875	51,185
Flour etc of meat, meat offal, fish, crust etc unfit for human consumption	0	1	0	0	0	346	1,382	2,094	3,164	4,137	7,222
Beet pulp, bagasse and brewing or distilling dregs and waste	0	3	0	0	0	108	416	1,150	2,977	3,060	7,104
Bran, sharps and other residues	0	1	0	0	0	119	125	702	6,332	5,968	3,332
Oil cake NES	0	0	2	0	0	25	0	0	261	0	2,712
Other vegetable material, waste, residues, by-products	0	0	0	0	0	427	117,59	19,767	12,284	24,090	169
Groundnut oil cake and other solid residues	0	0	0	0	0	0	0	0	179	0	
Total	6,573	19,307	21,501	27,862	41,760	47,520	54,909	90,255	120,547	113,224	216,298

Note: NES means not elsewhere specified or included. Source: (ITC 2014)

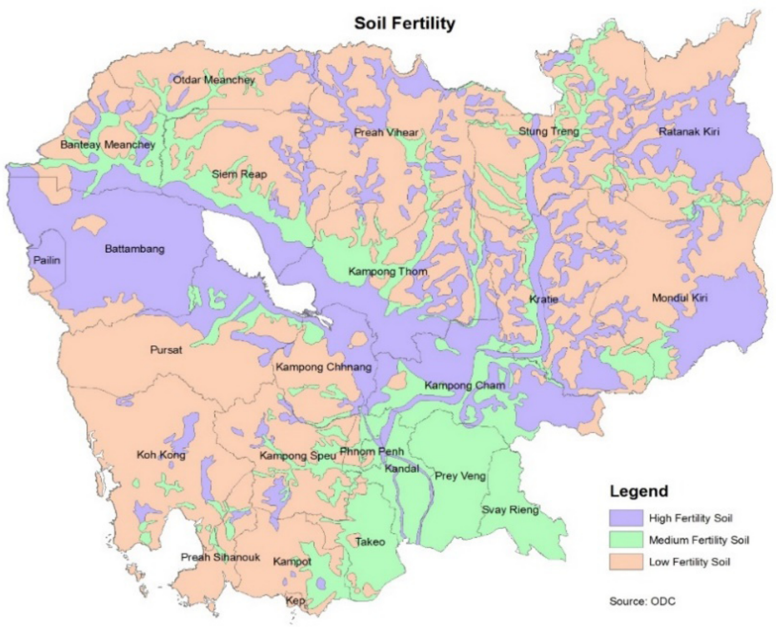
2. AGRICULTURAL RESOURCES

2.1 Soil and land

According to an agricultural census in 2013, nearly 50 percent of villages in Cambodia are located in fine sandy soil areas and 10 percent in regions with coarse sandy soil. Fine sandy soil is located in Svay Rieng, Koh Kong, Siem Reap, Kampot, Prey Veng, Oddar Meanchey, Kompong Chhnang, Kratie, Preah Sihanouk and Pursat. Because of closeness to the coast, more than 70 percent of villages in Kep province are located on a mixture of coarse and fine sand. This combination is also found in more than 50 percent of villages in the central and northern provinces of Kompong Speu, Stung Treng and Preah Vihear. Mineral-rich clay soil is found in more than 50 percent of villages in Battambang, Banteay Meanchey, Kratie, Kep, Preah Sihanouk and Pailin. Clayey soil is located in less than 15 percent of villages in Ratanakkiri province. Loam mixed with sand, silt and clay is located in more than 50 percent of villages in Stung Treng, Preah Sihanouk, Kandal and other provinces (NIS 2015a).

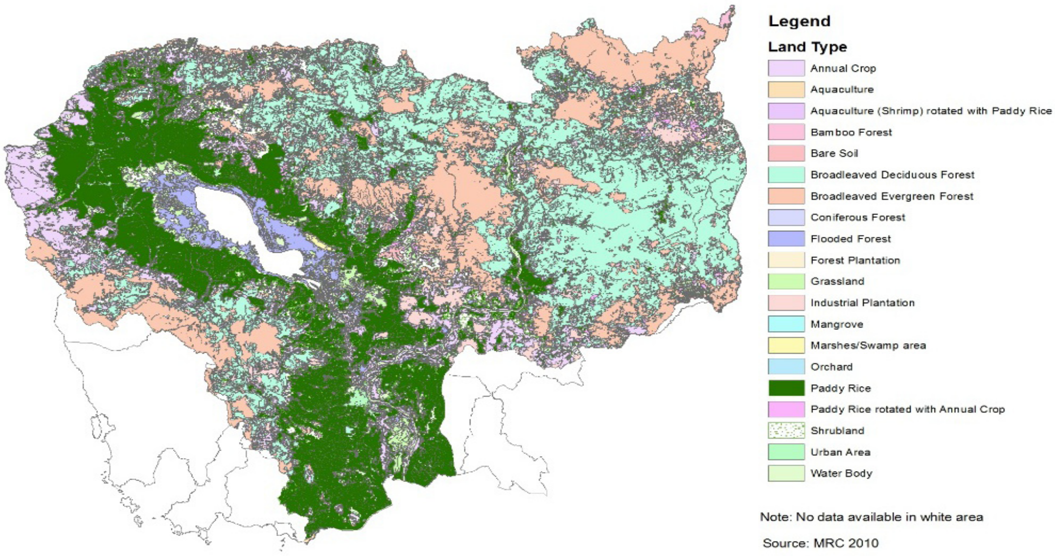
Land suitability for field crops is graded into five classes (from very low to very high) based on soil acidity, nutrient availability, surface condition, susceptibility of nutrient and structure decline in topsoil, rooting depth, water logging, inundation, water storage, workability, water erosion risk and phosphate export (Bell et al. 2005). Cambodian soil fertility is graded as high, medium or low (Figure 12 and Appendix 1).

Figure 12: Soil fertility



Source: (ODC 2016b)

Figure 13: Land cover in 2010



Source: (MRC 2010)

Land cover in Cambodia is: annual crops, about 1.42 million ha; broadleaved deciduous forest 4.03 million ha; broadleaved evergreen forest 2.82 million ha; paddy rice or paddy rice rotated with annual crops 0.29 million ha; and shrub land 1.39 million ha (MRC 2010). The data do not include Koh Kong, Preah Sihanouk, part of Kampot, Svay Rieng and part of Prey Veng because MRC data were available only for the Mekong basin (Figure 13 and Appendix 2).

Main land use

Temporary and/or permanent crops are grown in 70 percent of parcels within household agricultural holdings. Cambodian farmers use about one-third of parcels for their residences, and they use portions of these home lots for growing crops and/or keeping livestock and/or poultry. During the five years prior to the census, a very small percentage of parcels were left idle or used for other agricultural activities (temporary meadows, raising livestock and poultry etc). The average land under temporary crops is 0.79 ha, under permanent crops 1.27 ha and under a combination of temporary and permanent crops 1.34 ha (NIS 2015a).

Table 5: Average parcel size (ha) for various uses of land, for holdings with separate agricultural lands

	Cambodia	Plain Zone	Tonle Sap Lake Zone	Coastal Zone	Plateau and Mountainous Zone
All parcels	0.6	0.43	0.9	0.41	0.66
Land under temporary crops	0.79	0.54	1.25	0.45	0.8
Land under permanent crops	1.27	1.14	1.21	1.75	1.63
Land under temporary and permanent Crops	1.34	0.86	1.71	1.17	1.64
Land temporary fallow	1.29	0.85	1.34	2.27	1.32
Homelot with agricultural activities	0.12	0.1	0.13	0.16	0.12
Land under other land uses	0.56	0.22	1.58	0.53	0.31

Source: (NIS 2015a)

2.2 Water and irrigation infrastructure

Rice farming in Cambodia is highly dependent on rainfall rather than irrigation and lacks appropriate technology, which significantly limits productivity (World Bank 2015). Due to the significance of water management for rice production, the government and donors provide funding for supporting and expanding irrigation (CDRI 2011).

Surface water is an important source for irrigation. Inland water systems are mostly located in the central and eastern areas of the country. The Mekong and Tonle Sap Lake are the main inland water systems. The part of the Mekong in Cambodia is approximately 500 km long and has six main tributaries. Six streams flow into the Tonle Sap Lake through 32 channels. The Mekong is connected to the Great Lake by the Tonle Sap River. These rivers meet with the Basak river and the Lower Cambodian Mekong River at Chaktomuk, known as "*Quartre Bras*", in Phnom Penh. During the flood season, the Mekong's flow goes into the Tonle Sap River (11-23 percent), the Basak (12-14 percent) and the lower Cambodian Mekong River (62-68 percent) (CNMC 2000). At that time, the Great Lake expands to 900,000-1,400,000 ha (FISHERIES 2003). Irrigation schemes in Cambodia can be categorised as small (less than 200 ha), medium (200-5000 ha) and large (greater than 5000 ha). Most medium and large irrigation systems and some small-scale systems contain water reservoirs and canal systems. In Cambodia there are a reported 2403 irrigation schemes (1415 small, 955 medium and 33 large), which can potentially irrigate more than 1 million hectares (Thun et al. 2009).

Groundwater is progressively being used for small-scale irrigation, mainly for partial irrigation in the early and late wet season. It also used for supplementary irrigation of wet season rice and late-season recession rice. Access to groundwater is increasingly important in the double cropping of rice (Phaloeun et al. 2004; Johnston et al. 2015). Shallow alluvial aquifers in the Mekong lowlands allow farmers to install shallow dug and tube wells for growing dry season crops. Areas where groundwater irrigation is found include Siem Reap, Battambang, Kompong Chhnang, Kompong Cham, Prey Veng, Svay Rieng, Takeo and Kandal provinces (Johnston et al. 2015). Mechanised and treadle pumps are used for irrigation rather than hand pumps (iDE 2005). Farmers usually improve their own wells, although there are reports of farmers buying water from a neighbour's tube well (Johnston et al. 2015).

To increase the number of harvests per year, farmers use pumps during the dry season and sometimes also drain water from flooded fields. Pumps are effective for farmers when their areas lack large-scale irrigation infrastructure such as dams. Farmers recognise that pumps can help them during drought and in some cases flooding (World Bank 2015). From 2008 to 2013, irrigation pump sales increased 30 percent. In 2013, farmers paid an average USD53/ha and a high of USD115/ha (in Takeo province) for irrigation of dry season rice (Wokker, Santos, and Bansok 2014). Aside from pumps, individual investment in water management is still weak. In addition, most Cambodian farmers do not use more modern irrigation technologies such as drip irrigation and greenhouses (World Bank 2015).

Wet season supplementary irrigation is important for food security. According to MAFF (2012), around half (0.76 m ha) of the total wet season rice crop (1.45 m ha) has access to supplementary irrigation. The largest areas of current irrigation in Cambodia are suitable only for wet season irrigation; the dry season irrigated area is about 0.36 m ha (MAFF 2012). Irrigation of wet season rice is mostly used to reduce the risk of crop loss since it provides very low marginal returns. This discourages investment in infrastructure and maintenance, limiting the feasibility of cost recovery from irrigation service fees for wet season irrigation (Wokker et al. 2011).

The largest irrigated area was in the plains zone, 412,000 ha. The area in the Tonle Sap Lake zone was second, about half the amount of the irrigated area in the plains zone (Table 6).

Table 6: Area irrigated for cereals and grains (ha), by zone, in 2013

	Cambodia	Plain Zone	Tonle Sap Lake Zone	Coastal Zone	Plateau and Mountainous Zone
Non-aromatic rice	587,802	369,369	179,318	9,076	30,039
Aromatic rice	55,977	23,871	29,319	552	2,235
Sticky rice	5,861	4,637	1,106	38	80
Maize (young corn)	559	436	65	-	58
Maize (white/Yellow/Violet corn)	19,375	13,737	2,471	333	2,834
Sorghum	60	59	-	-	1
Other Cereals	99	82	-	17	-
Total	669,733	412,191	212,279	10,016	35,247

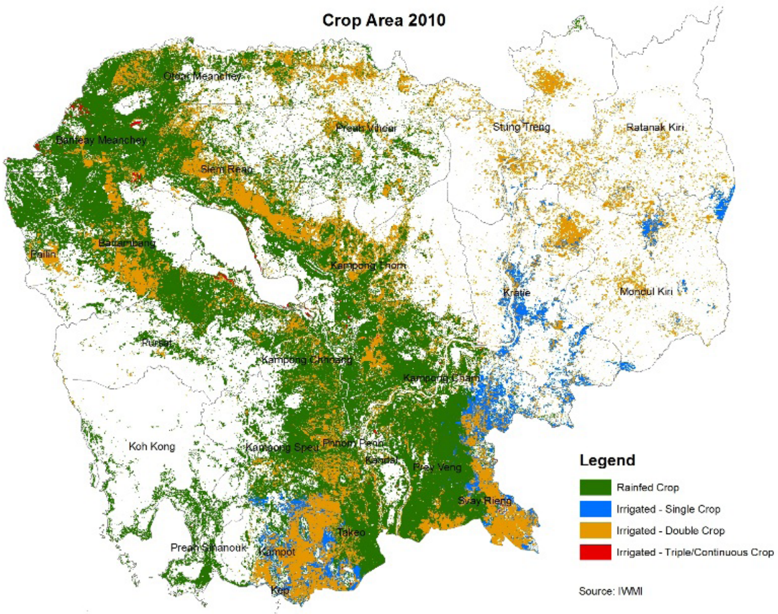
Source: (NIS 2015a)

2.3 Areas of single crop, double crop and triple crop

According to IRRA (2010), rain-fed crops increased from 3.38 million ha in 2000 to 4.65 million ha in 2010. Single irrigation crops increased from 0.15 million ha in 2000 to 0.46 million ha in 2010. Double irrigation crops increased from 1.37 to 2.42 million ha from 2000 to 2010. However, triple irrigation decreased from 0.31 to 0.03 million ha (Figure 14 and Appendix 3).

In 2014 around 50 percent of all villages in Cambodia grew only one crop per year; this was true of 80 percent of villages in the Phnom Penh area and in the provinces of Oddar Meanchey and Tboung Khmum. Double crops are produced in Pailin, where 90 percent of villages cultivate double crops, and Kep, Takeo, Kompong Cham, Kampot, Prey Veng, Kandal, Pursat, Battambang and Kompong Thom (NIS 2015a).

Figure 14: Crop area map of Cambodia in 2010



Source: (IRRA, 2010)

2.4 Agricultural chemical use

In 2013, farmers used about 153 kg/ha of fertiliser for rice in the dry season and only 66 kg/ha in the rainy season (Table 7). The main reason is that rainy season rice obtains fertiliser from natural sources or irrigation systems. In addition, dry season rice is commonly high-yielding varieties (mostly IR cultivars), which need large amounts of fertiliser (Theng, Khiev, and Phon 2014). However, in the plateau/mountain region, dry season rice cropping is shifting cultivation, so farmers there use small amounts of fertiliser during the dry season (Theng, Khiev, and Phon 2014). Table 7 shows average fertiliser use for different crops.

Table 7: Quantity of fertiliser used by crops (kg/ha, 2013)

Crop type	2007	2008	2009	2010	2011	2013
Dry season rice	232.9	245.9	181.4	229.2	183.7	153
Wet season rice	108.8	79.1	156	115.5	118.1	66
Corn	138.7	132.2	75.5	107.4	133.8	-
Cash crops*	163.5	174.4	125.1	146.1	112.1	-
Cassava	48.2	73.5	77.1	151.5	92.8	8
Vegetables	330.2	212	247.9	277.5	192.8	193
Other	222.4	107.7	192.4	187.6	145.6	-

* Cash crops are cowpeas, mung beans, grains, leguminous plants, sugar cane, groundnuts (peanuts), soy beans, sesame, oilseed, jute and kapok. Source: (Theng, Khiev, and Phon 2014); (World Bank 2015)

Fertiliser consumption fluctuates depending on its price (Theng, Khiev, and Phon 2014). Table 8 indicates that all kinds of crops in the Mekong area use more fertiliser than in the other regions. In 2011, fertilisers use for vegetables is highest in Mekong plain, plateau/mountain and coastal regions.

Table 8: Fertiliser Use by Region (kg/ha)

Quantity of fertiliser (kg/ha)						
	Mekong Plain			Tonle Sap		
	2007	2009	2011	2007	2009	2011
Dry-season rice	261.7	199.4	194.2	108.2	101.4	153.2
Wet-season rice	127.0	200.1	142.8	79.4	103.5	84.4
Corn	112.6	129.9	176.8	161.1	52.3	55.0
Cash crops	179.7	206.9	170.0	46.1	50.4	67.3
Cassava	48.2	82.8	95.8	0.0	27.2	85.3
Vegetables	365.0	293.4	203.8	141.2	201.6	71.9
Others	188.2	221.4	161.5	135.6	134.0	158.3
	Coastal			Plateau/Mountain		
Dry-season rice	0.0	182.2	179.4	50.4	61.3	177.0
Wet-season rice	163.3	141.0	105.2	93.3	124.4	126.4
Corn	377.5	39.9	174.5	0.0	25.2	50.4
Cash crops	342.9	195.8	145.5	65.0	52.8	69.4
Cassava	0.0	35.5	70.9	0.0	90.1	30.9
Vegetables	566.1	118.2	235.7	340.1	257.4	225.0
Others	416.1	179.1	116.7	118.6	104.0	89.1

Source: (Theng, Khiev, and Phon 2014)

Insecticide use on crops and vegetables is increasing. Farmers use insecticides on vegetables more than on rice, cassava and maize. In addition, the amount of insecticide used would increase, especially for vegetables (World Bank 2015). Nine out of ten farmers used pesticides for vegetables. One-third of respondents used pesticides for maize and rice, and less than 20 percent for cassava. The number of insecticide users is expected to increase, particularly for vegetable and maize production. These facts are related to food safety in areas where farmers are not completely aware of the risk associated with pesticide use and because of mismanagement by traders. In 2013, the ranking of farmers' expenditure on insecticides were USD82/ha (vegetables), USD12/ha (dry season rice) and less than USD4/ha (cassava, wet season rice and maize) (World Bank 2015).

Herbicide use is also increasing. Weed infestation is a major constraint on large-scale farming, particularly in upland areas. Cassava and corn farmers were the most frequent users of herbicides in 2013. Farmers tended to use herbicides because of a difficulty in finding workers. The figure indicates that herbicide use increased (2008-2013). Moreover, farmers estimated that the trend will continue for the next five years, mainly for cassava and maize. For irrigated rice, weed control by manual rotary is a better method, which needs only a few days of work per hectare. In 2013, farmers paid USD4.60/ha on herbicides for rainy season rice, USD33.80/ha for cassava, USD20/ha for maize and USD12.20/ha for dry season rice (World Bank 2015).

The spending on chemical fertilisers, pesticides, weedicides and fungicides was the highest cost of crop production in both seasons of 2014. In the rainy season, farmers spent about 603,000 million riels, approximately 25 percent of total costs. In the dry season they spent about 271,558 million riels, approximately 27 percent of total costs (Table 9).

Table 9: Cost of agricultural chemical use in 2014

Chemical fertilizers, pesticide, weedicide and fungicide	Cambodia	Phnom Penh	Plain	Tonle Sap	Coastal	Plateau/ Mountain
Million Riels						
Wet season	603,056	4,006	252,157	244,572	44,344	57,975
Dry season	271,558	2,434	209,912	41,980	7,628	9,604
Total	874,614	6,440	462,069	286,552	51,972	67,579
Percent						
Wet season	25.3	21.5	30.0	22.4	35.6	19.0
Dry season	27.4	27.9	33.4	19.3	31.5	8.7

Source: (NIS 2015b)

2.5 Agricultural labour

During 2005 to 2013, the number of working days declined for wet season rice (34 %), dry season rice (52 %) and maize (25 %. However, they increased for vegetables. During 2005, mixed vegetables and wet and dry season rice required more working days than other crops. However, dry season rice required fewer working days than wet season rice and other crops in 2013 (Table 10). Migration for work and mechanisation are the main factors influencing the agricultural labour structure, particularly female labour, for both family and hired labour. Firstly, migration for work affects agricultural labour in rural areas, especially among the young. Most young women who migrate for work do so to work in garment factories, where the average monthly salary is approximately USD162.50 per month, 50 percent higher than the agricultural hired worker salary of about 109 USD per month for 24 days of work. Young men work in construction, often in urban areas. In 2013, the average salary of construction workers was USD120 per month. Secondly, mechanisation also decreases agricultural labour. Previously, females often worked in harvest and post-harvest activities, but now the work is done by machines with male drivers (World Bank 2015).

Table 10: Use of labour in farm production, by crop, 2005 and 2013

	2005 (days/ha)			2013 (days/ha)	Change (%)
	Family	Hired	Total	Total	
Paddy (wet season)	30.3	42.7	73	48.29	-34
Paddy (dry season)	24.6	48.7	73.3	27.75	-52
Cassava	13.2	35.2	48.4	48.8	+1
Maize	15.6	26.2	41.8	31.33	-25
Vegetables (mixed)	79.8	60.1	139.9	169.85	+21

Source: (World Bank 2015)

The cost of hired labour for wet season crops is higher than for dry season. The Tonle Sap area had the highest cost of other hired labour charges in 2014 (Table 11).

Table 11: Cost of crop production of other hired labour in 2014

Other hired labour charges	Cambodia	Phnom Penh	Plain	Tonle Sap	Coastal	Plateau/ Mountain
Million Riels						
Wet season crops	575,614	1790	168,251	307,391	25,346	72,836
Dry season crops	174,141	971	93,990	39,843	7959	31,377
Total	749,755	2761	262,241	347,234	33,305	104,213
Percent						
Wet season crops	24.2	9.6	20	28.1	20.3	23.8
Dry season crops	17.6	11.1	15	18.3	32.8	28.3

Source: (NIS 2015b)

2.6 Agricultural extension and development

In the government's efforts to modernise agriculture, points still to be implemented include improving diversification, productivity and commercialisation; encouraging sustainable forestry and fisheries resources, livestock and aquaculture; and enhancing support services and human resources improvement. To achieve this, improved agricultural extension is important (MAFF 2015c). Government, private companies, non-government organisations and local associations provide agricultural extension services to farmers. The government is the main source (NIS 2015a). MAFF reviewed and invested in improving agricultural extension services between 2009 and 2013. Extension service workers are expected to provide training, particularly through the 556 agricultural cooperative organisations, in best practice techniques for land management, soil fertility and crop selection and support in organisation management, marketing, access to finance and agri-business development. The need for such communication, training and support is huge, and the government has recognised the requirement to extend the services to local levels (MAFF 2015a). Households in the plain and Tonle Sap Lake zones use agricultural extension more than other zones (Table 12).

Table 12: Agricultural households using extension services, by zone IS 2015a)

	Government	Private companies	Association within community	NGOs	Other sources
Cambodia	574,864	245,316	187,854	239,596	19,083
Plain Zone	249,318	118,260	71,426	81,214	6,531
Tonle Sap Lake Zone	218,401	97,864	76,232	101,486	9,063
Coastal Zone	35,552	3,648	13,988	12,353	938
Plateau and Mountainous Zone	71,592	25,543	26,210	44,542	2,552

Source: (NIS 2015a)

According to Theng, Khiev, and Phon (2014), the impact of agricultural extension services on rice productivity is positive but not statistically significant. A non-significant impact does not mean that the government does not need to focus on agricultural extension to improve rice production. However, it should focus more on solving the key challenges (CDRI 2014). Similarly, MAFF (2015c) found that agricultural extension issues that should continue to improve include system and regulations, human resources development, efficiency facilitation, supporting fund, technique and new technology, applicable technology and materials..

The MAFF found that agricultural extension policy needed to be organised and strengthened. This would help farmers and their communities to meet their needs and market demand. Farmers would be able better to decide about their production operations and agricultural commercialisation (MAFF 2015c).

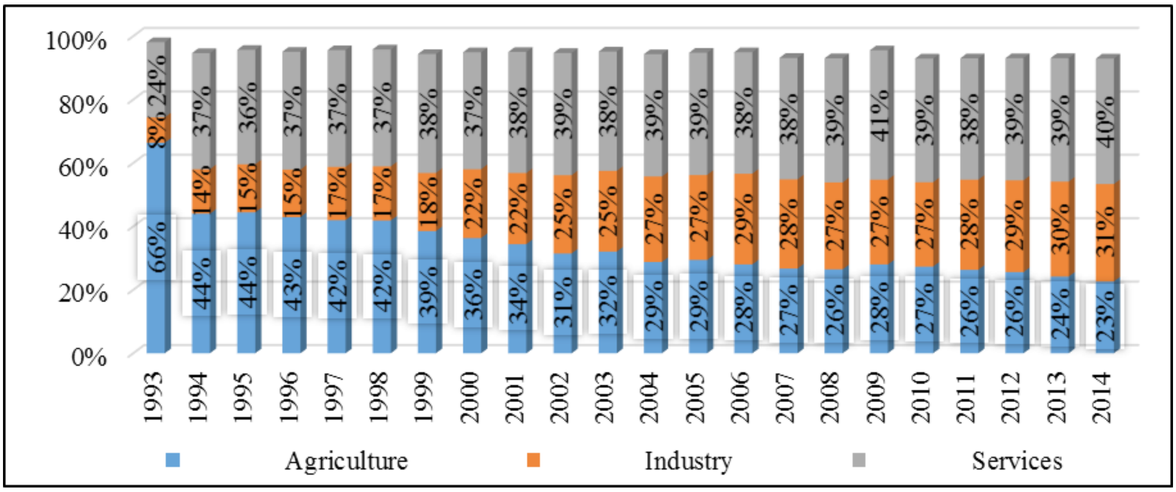
Farmers said that agricultural extension agents can't solve problems in some cases because their knowledge of agricultural techniques is limited (World Bank 2015). World Bank 2015 cited an example: "[A]gents promoted techniques requiring good water control to farmers who did not have irrigated land; or disseminated technical packages that would not be profitable because of high initial. Farmers wanted extension agents to ultimately discuss adoption based on the specific assets, soil quality, and fertility associated with their farms. In an ideal situation, such tailored advice would be provided to farmers, but this approach may face high costs of intervention and may only be possible for medium-size and large farms, excluding the more numerous small farmers" (W p. 44).

3. AGRICULTURAL SOCIAL AND ECONOMIC SETTINGS

3.1 Agriculture's contribution to GDP

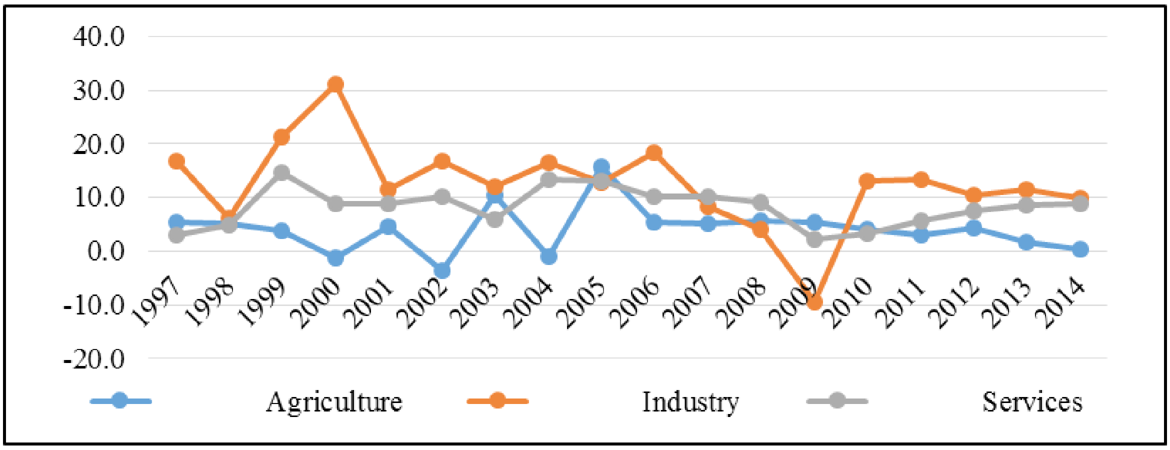
Agriculture contributed about 22.65 percent (constant 2000 price) of GDP in 2014. Industry contributed 30.71 percent and services 39.57 percent (Figure 15). The share of agriculture decreased from 27.33percent to 22.65 percent (2010-2014). The growth of real GDP of agriculture was 0.3 percent in 2014. Industry grew 9.8 percent and services 8.7 percent (Figure 16).

Figure 15: Percent distribution and of GDP (constant 2000 prices) 1997-2014



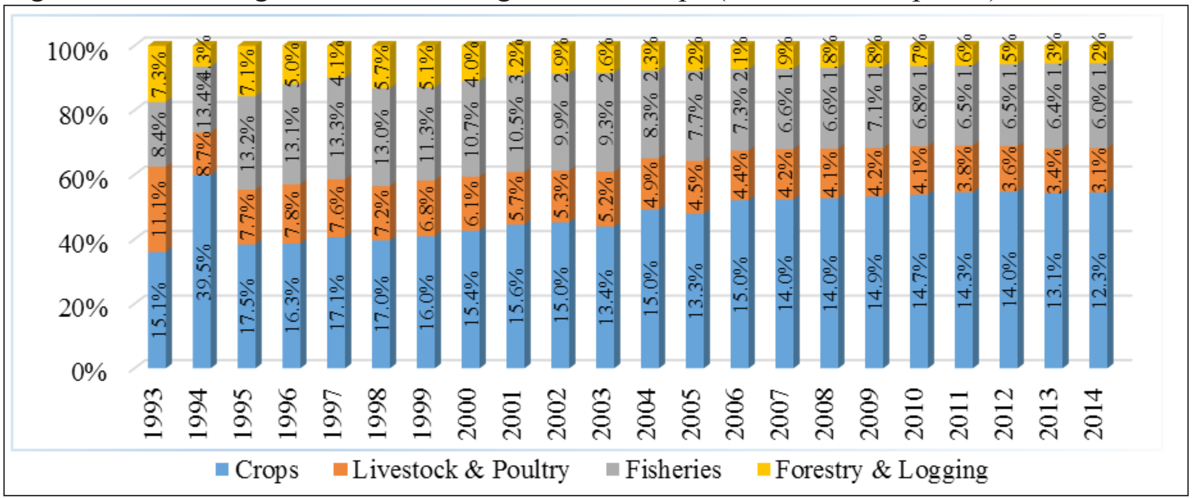
Source: (ADB 2015; NIS 2014)

Figure 16: Sectoral growth of GDP (constant 2000 prices) 1997-2014



Source: (ADB 2015; NIS 2014)

Figure 17: Percentage distribution of agricultural crops (constant 2000 prices), 1993-2014



Source: (NIS 2014)

The percentage of crops, livestock and poultry, fishing, forestry and logging decreased from 2009 to 2014. Crops decreased from 14.9 percent in 2009 to 12.32 percent in 2014. Livestock and poultry decreased from 4.2 percent in 2009 to 3.1 percent in 2014. Fishing decreased from 7.05 percent in 2009 to 5.96 percent in 2014. Forestry and logging decreased from 1.82 percent in 2009 to 1.22 percent in 2014 (Figure 17).

3.2 Foreign exchange earnings

Agriculture generates employment and production for domestic consumption and export (Hang, Socheth, and Chandarany 2011). During 2004-06, fish and crustaceans, rubber and rubber articles, and wood and wooden articles generated the highest foreign exchange earnings among 11 major agricultural exports. Wood and rubber were among the three top agricultural exports during 2007 to 2013. However, fish and crustaceans were surpassed by cereals (Table 13).

In 2013, the foreign exchange earnings of cereals increased 85 percent compared to 2012. Exports of vegetables increased 58 percent. However, the exports of live animal and fish decreased 87 percent and 30 percent, respectively (Table 13).

Table 13: Major Cambodian agricultural exports, 2004–13 (USD million)

HS	Product	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
01	Live animals	1.16	0.01	0.08	0.07	0.10	0.15	0.10	0.41	0.43	0.06
03	Fish and crustaceans	13.14	10.13	5.00	2.96	2.24	4.03	2.84	3.13	1.70	1.18
04	Dairy products; bird eggs	-	0.01	-	-	0.07	-	-	0.02	0.00	0.00
06	Live trees and other plants	-	-	0.00	0.02	0.01	-	0.04	0.00	0.00	0.08
07	Edible vegetables and roots	0.81	0.17	0.07	1.17	0.49	1.01	0.84	2.53	8.59	13.59
08	Edible fruits and nuts	0.26	0.98	0.32	0.46	1.22	0.89	0.13	0.59	0.86	0.50
09	Coffee, tea and spices	0.01	0.05	0.18	0.46	0.72	0.46	0.11	1.44	0.96	4.32

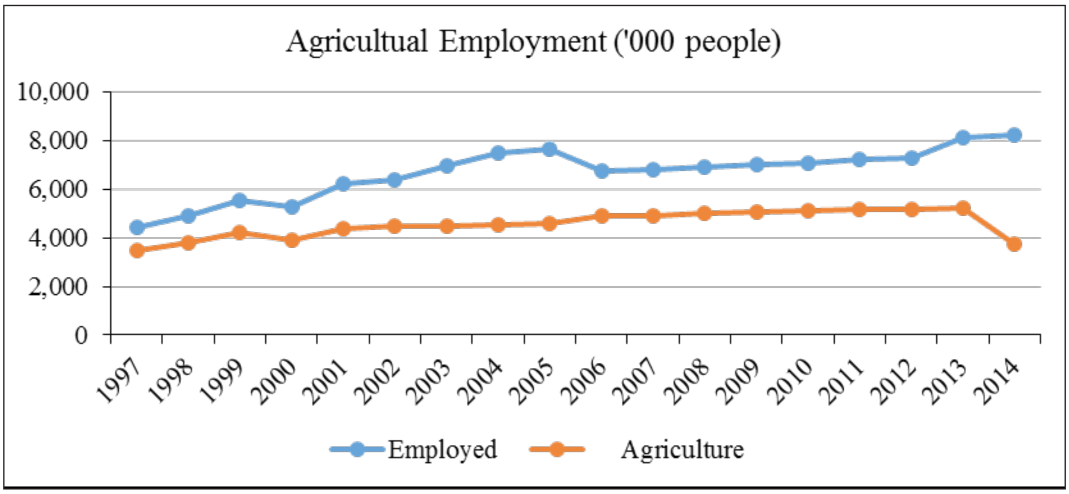
10	Cereals	5.78	3.86	2.92	5.43	4.86	12.63	37.28	107.88	139.96	259.68
14	Vegetable planting materials	0.02	0.08	0.19	0.25	0.07	0.06	0.01	0.01	0.03	0.05
40	Rubber and rubber articles	38.33	36.60	46.12	42.98	33.70	51.69	86.86	192.22	168.31	180.18
44	Wood and wooden articles	9.43	9.58	9.96	9.00	3.55	4.77	37.90	52.21	21.37	69.66

Source: : (UN 2016); mirror data: http://comtrade.un.org/data/, accessed 26 February 2016

3.3 Contribution to employment

Agriculture employs many people in Cambodia. Agricultural employment increased during 2001 to 2013, although overall employment declined during 2006 to 2012. However, agricultural employment declined in 2014, while total employment increased. Agriculture supplied 4,384,250 jobs, and it increased to 5,225,700 in 2013. However, it decreased to 3,727,000 in 2014 (Figure 18).

Figure 18: Agricultural employment, 1997-2014



Source: (ADB 2015)

3.4 Social structure of agriculture

Cambodian agriculture is moving from subsistence to commercial farming, producing not only for domestic consumption but also for processing and export. The change could be due to increasing crop productivity, diversification and agricultural inputs and machinery use. The main contribution to household incomes in rural Cambodia is agricultural crops. According to the Cambodia Socio-Economic Survey (CSES), the real average per capita daily income of people in rural areas from agricultural crops more than doubled within five years, from 507 riels in 2004 to 1101 riels in 2009 (Sobrado et al. 2014).

Rice is a main source of increasing income among the rural households because rice is grown on 84 percent of Cambodia's cultivated land (about 3 million hectares). About 85 percent of rural people are rice farmers. The estimated paddy surplus of approximately 2 million tons in 2005, 2.2 million in 2006 and 2.6 million in 2007, assuming a price of USD205/ton, translates into USD750 million to 1 billion for the rural economy beginning in 2008. In 2013, rice production reached 9.38 million tons and produced a surplus of approximately 3.09 million ton (4.82 million tons of surplus paddy), an increase of 23.78 percent and 37.68 percent over

2009, respectively. The causes of rice expansion were high prices and increasing yield; the average farm size has not changed but the cultivated area expanded from 2.3 million ha in 2004 to 2.6 million in 2007 (Sobrado et al. 2014). The increasing price enabled farmers to enhance their incomes substantially. The price of rice increased about 134 percent in Vietnam and 88 percent in Thailand while the retail price in Phnom Penh increased 119 percent. However, increasing prices of some inputs such as labour, fertiliser and fuel caused farmers to raise the rise of price from early 2008, and they also benefited from increasing yield. The wet season rice yield increased from 2.6 tons/ha in 2009 to 2.9 tons in 2011, but there was a small decrease to 2.8 tons/ha in 2014. The dry season yield increased from 4.1 tons/ha in 2009 to 4.4 tons in 2011 and then remained unchanged to 2014 (MAFF 2015b). The surplus enables the change to commercial farming.

3.5 Land tenure

Owned agricultural land is the most common land tenure (about 89 percent). Rented out land is about 6 percent, rented in land about 4 percent and free use of land about 1 percent (NIS 2015b). From 2009 to 2014, the share of owned parcels declined 4 percent. The number of owned parcels in the plain and Tonle Sap zones is higher than the other zones. The percentage of owned parcels is highest in the coastal and plateau/mountain zones (Table 14).

Table 14: Number of agricultural parcels, by ownership and zone, 2014 (in thousands and percent)

Land Tenure	Cambodia	Phnom Penh	Plain	Tonle Sap	Coastal	Plateau/ Mountain
	Number					
Owned	2996	25	1238	980	229	523
Owned, rented out	196	5	97	69	8	17
Rented in	129	1	64	48	7	9
Free use of land	36	1	14	15	1	6
Other tenure	2	0	0	0	0	1
Total	3358	33	1413	1113	245	555
	Percent					
Owned	89.2	77.6	87.6	88.1	93.6	94.2
Owned, rented out	5.8	16.3	6.8	6.2	3.2	3
Rented in	3.8	4.5	4.5	4.3	2.7	1.6
Free use of land	1.1	1.6	1	1.3	0.5	1
Other tenure	0	0	0	0	0	0.2
Total	100	100	100	100	100	100

Source: (NIS 2015b)

About 88 percent of the total area of agricultural land was farmed by its owner (NIS 2015b). The area was highest in the Tonle Sap and plains zones, while the percentage share of such properties was highest in the coastal and plateau zones (Table 15).

Table 15: Area of agricultural land by ownership and zone, 2014 (in thousand ha and percent)

Land Tenure	Cambodia	Phnom Penh	Plain	Tonle Sap	Coastal	Plateau/ Mountain
	Thousand hectares					
Owned	2999	18	943	1233	188	616
Owned, rented out	217	3	83	103	6	22
Rented in	149	1	63	70	5	10
Free use of land	23	0	8	10	0	4
Other tenure	1	0	0	0	0	1
Total	3389	23	1097	1416	200	654
	Percent					
Owned	88.5	80	86	87.1	94.2	94.3
Owned, rented out	6.4	15.4	7.5	7.2	3.2	3.4
Rented in	4.4	4.4	5.7	5	2.4	1.6
Free use of land	0.7	0.3	0.7	0.7	0.2	0.6
Other tenure	0	0	0	0	0	0.1
Total	100	100	100	100	100	100

Source: (NIS 2015b)

3.6 Market access

In 2013, farmers obtained the highest total revenue, total variable costs and gross margins per hectare from growing vegetables. They received the highest total revenue and gross margins from maize in 2005. The total variable cost of dry season rice was highest in 2005 compare with other crops (World Bank 2015). Comparing revenue, variable costs and gross margins between the two periods, vegetables were most advantageous among all crops. Comparing the five main crops, total revenue per hectare ranked (1) vegetables, (2) cassava, (3) dry season rice, (4) wet season rice, (5) maize (Table 16). The nett income per hectare of modern farming was higher than for traditional farming for all crops. The nett revenue from vegetables was the largest difference and from wet-season rice the smallest (Table 16).

According to NIS (2015b), in 2013, approximately 70 percent of Cambodian agricultural households knew the location of the nearest market for harvested crops. However, only 22 percent of them had never used those markets for selling their produce. The percentage of people aware of the nearest market for agricultural produce was highest in the coastal zone. The distance to market was the most common problem for households in the Tonle Sap Lake and plateau/mountain zones. Farmers had to travel one to two hours to reach their nearest market. However, a small percentage of households in both areas travelled more than two hours to reach their nearest market (NIS 2015b). Approximately 50-60 percent of the households in these zones spent less than 30 minutes to access their nearest agricultural market. About one-third of the households in all zones spent more than 30 minutes and less than one hour to sell their produce in the nearest market. From 13 percent to 15 percent of household in Tonle Sap Lake and plateau zones spent one to two hours to access the nearest market. From 3 percent to 7 percent those zones spent more than two hours to access the Nine out of 10 households took their produce to market using different type of vehicles; about 6 percent used draught animals; and 4 percent walked (NIS 2015b).

Table 16: Comparison of key farm budget indicators, $/ha, Cambodia, 2005 and 2013

Total Revenue	2005 (USD/ha)	2013 (USD/ha)	Change (%)
Cassava	375	1,297	246
Maize	708	744	5
Wet season rice	345	756	119
Dry season rice	398	992	150
Vegetables	433	2843	556
Total Variable Costs			
Cassava	178	791	346
Maize	134	440	229
Wet season rice	186	510	174
Dry season rice	202	697	245
Vegetables	149	1449	893
Gross Margins			
Cassava	198	506	156
Maize	577	304	-47
Wet season rice	159	245	55
Dry season rice	195	296	51
Vegetables	284	1394	380

Source: World Bank 2015

3.7 Constraints and challenges

The development of agricultural productivity and production in Cambodia also have challenges (MAFF 2015a).

Farm inputs

Fertilisers: Farmers cannot apply appropriate amounts of fertiliser because of its increasing cost. Furthermore, fertiliser use is significantly influenced by quality (FAO 1981). Fertiliser issues of concern include licences, which encourage rent seeking and stimulate illegal imports, and restrictions on imports by MAFF. Below standard products were imported because of drawing back market principles and force import from neighbouring countries. Moreover, limited quality control and inspection at the border allow the import of below standard products. Quality is still a problem because of limited regulation of fertiliser operators. About 10 percent of farmers meet problems of fake fertiliser, losing USD285-350 as a result (Vuthy., 2013).

Seeds: Farmers can increase their rice yields by about 18 percent by appropriate seed selection, but the supply of improved seed is still limited (FAO 1953). Suppliers can meet only about 20 percent of total demand. Most farmers use their own seeds. To improve rice exports, 10 high-quality varieties have been promoted, but farmers cling to their preferred choices or varieties, for instance IR 504 from Vietnam (Vuthy 2013).

Extension: Technical knowledge and support are important for increasing crop yields (MAFF 2015b). Most farmers still use traditional practices that inhibit agricultural growth (Vuthy 2013). Extra training and support by agricultural extension workers are still required (MAFF 2015b). Links between research and extension of seeds, fertiliser usage and pest control are weak (Vuthy 2013). Human resource development and vocational and professional training require enhancing, especially local agricultural technical capacity. Moreover, technical field staff specialising in agriculture, fishery and forestry need to work more at the grassroots level (MAFF 2015b).

Irrigation: Irrigation in Cambodia dates back to the Angkorian period. Sixty-nine percent of irrigation schemes were constructed during and after the 1970s (Chou 2010; Perera 2006). Unfortunately, most of these schemes have broken down because maintenance still depends mostly on funding from donors and because of faulty design (Perera 2006; CEDAC 2009; De Silva, Johnston, and Sellamuttu 2014). Cambodia has 2525 irrigation systems (CEDAC 2009); however, most are not efficient because of inappropriate maintenance and operation (De Silva, Johnston, and Sellamuttu 2014; CEDAC 2009; Thuon et al. 2007). About 570 schemes are located in the Tonle Sap basin zone, but only approximately 195 are fully operational (Chea et al. 2011). CEDAC (2009) found that 23 percent of the 2525 irrigation schemes operated only during the dry season and 49 percent in both seasons. Very few farmers can access irrigation water in both seasons. According to MOWRAM (2009), the total area under paddy cultivation was 2,615,741 ha and about 1,120,246 ha (42.82 percent) were irrigated in 2008. The area under irrigation was 773,188 ha for wet-season and 773,188 ha for dry-season (MOWRAM 2009).

Another study found that most irrigation systems were originally designed and constructed for wet season crops only (Chea et al. 2011). As well, CEDAC (2010) found that more than 2400 irrigation systems required rehabilitation or reconstruction. Poor operation and maintenance have been emphasised as weak points of irrigation schemes in Cambodia (De Silva et al. 2014). The limited technical and institutional capacity of stakeholders is a main constraint for irrigation improvement (De Silva, Johnston, and Sellamuttu 2014). Furthermore, the current participatory irrigation management and development of many schemes do not encourage farmers to pay irrigation service fees and participate fully in management (De Silva, Johnston, and Sellamuttu 2014). Until now, farmers who irrigated depended on natural sources or constructed reservoirs filled by rainfall. Most farmers have no access to irrigation for dry season crops (Chea et al. 2011). This leads to water scarcity and conflicts (Perera 2006; Vuthy and Ra 2010).

Farm credit: There is very little long-term capital available for investing. In rural financial services (MAFF and MOWRAM 2010). Lack of access to formal credit remains a constraint for poor smallholders. No collateral (even small plots land) and high risk of crop failure make MFI reluctant to loan. Informal credit offers greater flexibility, but the interest rate is high, around 5 percent per month. MFI interest rates also remain high, about 2.5 percent per month. High costs of fertilisers, pesticides and fuel, and low returns provide few incentives to use credit to increase production. There is no vertical integration of seed, extension services, credit and inputs (Vuthy 2013).

Land ownership: CDRI in 2011 found that most rural Cambodian households suffer from landlessness or near landlessness or lack of formal property rights to land. This is a major driver of widespread rural poverty and a limitation on agricultural productivity growth (Mulia et al. 2010). According to CSES data, about 15 percent of farmers are landless and about 40 percent own less than one ha. Land for economic land concessions (ELCs) is distributed faster than land allocation for social and economic development (LASED). Approximately 55 percent of rural households require more land to secure their food needs. However, LASED is very slow. Some ELCs provide benefits for rural communities, but negative impacts are appearing: land grabbing, non-productive land use, loopholes in land titling (Vuthy 2013).

Trade—value chain analysis: Farmers have few benefits: high production costs, low yield because of lack of technique, low farm gate price (no bargaining power) and low net return (about 21-26 percent of total crop value). The rice market is highly dependent on informal trade with Vietnam and Thailand, and demand and prices are unstable (Vuthy 2013). Finding markets and increasing competitive ability are the main problems for farmers (MAFF 2015a). Cambodia has no technical guidance or information on prices and products with high export potential for farmers such as Thailand and Vietnam do (Vuthy 2013).

Investment: The increasing opportunities for private investments in agriculture are important and should be encouraged. Many companies have invested in agro-industrial crops through economic land concessions. However, some investors have not carried out their contracted investment plans and have left the land uncultivated. These companies are subject to confiscation of the land and cancellation of the contract. Monitoring of contract implementation must be strongly enforced (MAFF 2015a).

Contract farming—rice: Contractors manage and control the whole process of contracting. Usually, farmers are not consulted about contract terms; they just agree or disagree. Produce quality is judged solely by contractors. Due to the complex terms and few benefits, many contracted farmers have left the schemes. The existing model is outdated because the contract is only between the individual farmer and contractor, with the farmer having no bargaining power and few benefits (Vuthy 2013).

Producer organisations: Their establishment and operation depend on assistance from NGOs and provincial department of agriculture, approximately 14,000 groups nationwide, including 240 agricultural cooperatives. There are poor organisational structures, poor leadership and weak planning skills. Activities stop when support agencies discontinue their services, even in successful groups. Members have access to production techniques only, not linked to input and output markets. Farmer organisations are in an early stage of development and need to build trust and links to markets. Due to lack of horizontal linkages and coordination of farmer organisations and contracting schemes, smallholders obtain fewer benefits (Vuthy 2013).

Challenges for exports: Constraints related to product quality include diverse varieties of produce, poor post-harvest treatment (drying and storage), lack of a paddy market because of unstable paddy procurement and incomplete market systems. Milling has some constraints: a shortage of large mills to meet the milled rice export target of 1 m tons, high energy costs, low milling technology (below standard quality for exports) and lack of working capital to buy paddy. Transportation is another constraint, being mostly by road at very high cost (USD15/ton). Port capacity, despite expansion, is presently insufficient to handle 1 m tons of milled rice. In addition, export procedures are time consuming and costly (USD20/ton). SPS constraints include no export experience, overlapping responsibilities (competition for gatekeeper power) and poor coordination between ministries caused by overlapping roles. The development of post-harvest management is still limited despite recent investment. To attract further significant investment and reduce informal exports, the environment for trade requires further improvement (MAFF 2015a).

High exposure to risk and lack of crop insurance: MAFF (2016) the high exposure of Cambodian farmers were flood and drought. Annual affected area and destroyed area by the both risks are recorded by Ministry of Agriculture, Forestry and Fisheries. RGC (2010b) reports that lake of crop insurance because of pests or extreme weather or pests.

High energy costs which contribute to production costs: ADB (2012) reported that all oil consumed in the country is imported, and 25 percent of it is used for electricity. The cost of fuel impacts farmers because they use diesel fuel for pumps and/or irrigation. The increasing cost of fuel is increasing the costs of local and industrial transport and agricultural inputs. The cost has increased three times compared with in 2011.

Lack of incentives to upgrade production: Farmers invest little in better inputs, machinery or infrastructure because of low margins. Prices of agricultural produce have not matched higher costs of farm inputs (MAFF and MOWRAM 2010).

Lack of post-harvest technologies and facilities: ADB (2012) noted that post-harvest and milling damage of rice is high. Farmers need to sell their excess grain immediately after harvest because they lack the facilities and expertise for timely and efficient threshing, handling, drying, storage and processing. Selling immediately also helps farmers to ease their debt burdens. Local evaluations found that, from harvest to storage, grain loss was 20 to 50 percent, and grain loss in milling was as high as 30 percent. After harvesting, farmers sold their additional rice immediately because they were poor and their storage facilities were limited.

Livestock disease: The increase of livestock production has slowed because of infectious diseases, shortage of facilities for disease prevention and meat producer competition for animal feed and medicines (MAFF 2015a).

Challenge of flooded forest: More effective measures are required to protect flooded forests. Of concern are the limited human and financial resources for combating inland and marine fishery offences. Flooded forest and fishery demarcation and elimination of fishery offences are still to be addressed by public authorities and local communities. There is competition between fishing and other uses for water, including for power, principally dam construction on the upper Mekong (MAFF 2015a).

4. AGRICULTURAL POLICY

4.1 Review of current agricultural policy

Agricultural policies are essential to agricultural development. Some main policies have been updated recently: Rectangular Strategy (RS) II updated to III, National Strategic Development Plan (NSDP) 2009-2013 updated to 2014-2018, and Agricultural Strategic Development Plan 2009-2013 updated to 2014-2018 (Table 17).

Table 17: Current agricultural policies in Cambodia

National
Rectangular Strategy III (2013) The goal is to increase agriculture value added through: • Improved and modernised post-harvest handling, infrastructure and technologies to reduce losses and increase product quality; • Speciality and high-value crops: fragrant and organic rice, cashews, corn, mung beans, soy beans, sesame, pepper, silk, fruit, coffee beans, vegetables and flowers; • Integrated livestock-fish production to meet market demand for meat, fish and dairy products; • Investments in food processing, marketing and distribution; • Higher productivity production and sales through modernising and commercialising subsistence agriculture (RGC 2013).
National Strategic Development Plan 2014-18 NSDP 2014-2018 supports RS III, specifically implementation of Rectangle 1: Promotion of Agriculture Sector which comprises four elements: crop productivity and output diversification and commercialisation; integrated livestock-fish farming; land reform and land release through clearing farmland of mines and unexploded ordnance; and stewardship of environmental assets for livelihood security (RGC 2015).
Promotion of Paddy Rice Production and Export 2010 Policy actions focus on four key areas: rice production; rice post-harvest collection, milling and processing; rice logistics management; and rice marketing solutions and branding (RGC 2010a).
Sectoral
Agricultural Strategic Development Plan 2014-18 Achieve annual agricultural growth of 5% by: • Increasing agricultural production and productivity • Forming a strategy for diversification • Supporting agricultural commercialisation and trade • Promoting livestock and fish production • Paying greater attention to sustainable, community forestry and fisheries management (MAFF 2015a).
Strategy for Agriculture and Water 2010-13 • Improve food security and income for rural households • Produce agricultural surpluses for export • Build resilience of rural households • Promote sustainable land and water resources management (MAFF and MOWRAM 2010)
Action Plan for Implementing Policy Paper on the Promotion of Paddy Production and Rice Export Rice 2011 • Transform informal rice trade to formal rice export through intensifying rice production to meet market demand (MAFF 2011)

Agricultural Extension Policy in Cambodia 2015 Under the theme "Extension Services for Better Well-being", key objectives are to: • Improve agricultural extension services provision at all levels by reforming the institutional framework to strengthen cooperation, coordination and linkages between stakeholders; • Build capacity and skills of extension agents to deliver services that respond to the various needs of local farmers and marketing activities; • Invest in research and development to design appropriate technologies that are affordable, accessible and acceptable by the farmers who most need them; • Set up an agriculture information exchange as a means to develop and distribute extension materials, and provide access to and promote adoption of new agricultural knowledge and technologies; • Increase farm productivity, diversification, commercialisation and income through extension services that help farmers make better decisions to achieve their goals (MAFF 2015c).
Strategic Planning Framework for Fisheries 2010-2019 (CAMCODE [Cambodian Code of Conduct for Responsible Fisheries]) • *Establish principles* in accordance with agreed best practices, evidence and national laws, for the responsible development, management and conservation of fisheries and other aquatic resources (inland and marine). • *Provide guidance* using appropriate formulation and implementation of international agreements and other legal instruments, both binding and voluntary. • *Guide policy making and planning* within the sector to achieve equitable, sustainable and coordinated development in line with national development policies and plans. • *Increase transparency, accountability and harmonization* throughout the improvement of the fisheries part. • *Develop coordination in the fisheries sector* between different stakeholders, and foster a greater sense of partnership between different stakeholder groups in conservation, management development, and use of fisheries. • *Promote more responsible development* for sustainable and equitable fishing, aquaculture, rice field fisheries, post-harvest fisheries and ancillary industries (RGC 2011).

4.2 Existing agricultural policy directions and implications

The **NSDP Update 2009-2013** assigns roles responsibilities for implementing priority policies in each area of RS II, and sets out institutions' respective action plans and estimated costs for carrying them out. Over the duration of NSDP 2009-2013, Cambodia experienced average annual economic growth of 7 percent. For the first time GDP per capita exceeded USD1000, and the poverty rate dropped to 19 percent in 2011. Also, strong government commitment meant that Cambodia achieved most of the targets of its Millennium Development Goals. These remarkable results coupled with lessons learned convinced the government that the Rectangular Strategy for Growth, Employment, Equity and Efficiency remained essential and appropriate for the fifth legislature of the National Assembly. The four rectangles of the RS were retained and their coverage expanded, and policy priorities and mechanisms were consolidated. RS Phase III reaffirms the national vision for the country's continued sustainable development and poverty alleviation in response to the expectations and aspirations of its people. NSDP 2014-2018 was designed to support the achievement of RS III (RGC 2015).

The **Agricultural Sector Strategic Development Plan 2009-2013** was closely aligned with NSDP 2009-2013 and RS II. Despite farmers' continued dependence on adequate and timely rainfall and favourable weather, there were noticeable improvements in the production of rice and other crops. Rice production in 2013 stood at 9.38 million tonnes, and rice surplus amounted to 3.09 million tonnes. This was achieved through two main factors: the cropping area was expanded, especially for dry season (double) cropping; and rice yields increased. Smallholder agriculture production also increased, including subsidiary, industrial, crops and permanent crops, as did the outputs of medium- and large-scale farmers. The rubber plantation area increased considerably, with remarkable growth in smallholder rubber plantations. Livestock production has developed, with a strong increase in pig and poultry production and a focus on commercial beef cattle fattening (MAFF 2015a).

The **Policy Paper on the Promotion of Paddy Production and Rice Export** articulates the national objective of producing a paddy rice surplus of more than 4 million tonnes rice and being capable of officially exporting more than 1 million tonnes of milled rice by 2015. MAFF's detailed action plan involved critical policy measures in four main areas: (1) increasing rice productivity: expand cultivated rice area 12.26 percent to 3.05 million ha by 2013, increase rice yield 11.52 percent to 3.163 tonnes/ha by 2013, release 10 rice seed varieties (Sen Pidao, IR 66, Chulsa, Phka Rumduol, Phka Romdeng, Phka Romeat, Phka Chan Sen Sar, Riang Chey, CAR 4, and CAR 6), implement further agricultural research and technologies, and promote system of rice intensification (SRI) methods; (2) paddy rice collection and processing: creation of farmer organisations (FOs), release Law on Agricultural Cooperatives, and deliver agricultural extension services to strengthen FOs' technical and business capacity; (3) export facilitation: implement a One Window Service for rice export, select Phka Rumduol for "World's Best Rice" award (won the title in 2012, 2013 and 2014); and (4) marketing support: disseminate domestic, regional and international rice prices via radio, television, short message services (SMS), bulletins and MAFF its website. Other ministries are promoting the Cambodian rice brand at international trade fairs (MAFF 2015a).

A series of **fisheries reforms** rolled out over the last 10 years achieved their aim of greater access to inland fishing grounds for local fishers and the creation of community fisheries (CFi) for the sustainable use, management and conservation of fishery resources. The main policy action was to revoke (and then in 2012 abolish) private fishing lots. Supportive policy steps entailed establishing a department to support CFi; training for CFi committees; and putting in place legal and regulatory framework determining CFi mandate to manage fishing grounds (De Silva, Johnston, and Sellamuttu 2014).

4.3 Current agricultural legislation, regulation and governance

Between 2010 and 2015, the government promulgated several laws and sub decrees aimed at country-wide improvements in agriculture. Two important laws – Law on Farming Community, and Law on Community Agriculture– were established in 2013 and 2015, respectively. These were accompanies by the Sub-Decree on the Agricultural Census in Cambodia 2013, Sub-Decree on Contract Farming Production, and Sub-Decree on the Establishment of Alternative Food Supplies System in Cambodia. At the same time, government also issued five important Proclamations and two Decisions with a view to improving fisheries and cropping. Other laws, royal decrees, sub-decrees, proclamations and decision are listed in Table 18.

Table 18: Laws, royal decrees, sub-decrees, proclamations and decisions on agriculture and fishing, 1970–2015

Laws	Promulgation Date
Law on Community Agriculture	9 May 2015
Law on Farming Community	9 Jun 2013
Law on Seed Management and the Rights of Plant Breeders	!3 May 2008
Law on Fishery	21 May 2016
Royal decrees	
Kret-Chbab on Fishery Management	9 Mar 1987
Royal Decree on the Establishment of Community Fisheries	1 Jan 1970
Sub decrees	

Sub-Decree on the Management and Administration of Agricultural Land	6 Apr 1985
Sub-Decree on Community Fisheries Management	20 Mar 2007
Sub-Decree on the Agricultural Census in Cambodia 2013	4 Dec 2012
Sub-Decree on the Cancellations and Reduction of Fishing Lots to be Reserved for Family Scale Fishing in Battambang Province	15 Dec 2000
Sub-Decree on the Cancellations and Reduction of Fishing Lots to be Reserved for Family Scale Fishing in Kampong Cham	22 Jan 2001
Sub-Decree on the Cancellations and Reduction of Fishing Lots to be Reserved for Family Scale Fishing in Kampong Chhnang Province	21 Jan 2001
Sub-Decree on the Cancellations and Reduction of Fishing Lots to be Reserved for Family Scale Fishing in Kratie Province	22 Jan 2001
Sub-Decree on the Cancellations and Reduction of Fishing Lots to be Reserved for Family Scale Fishing in Phnom Penh	16 Feb 2001
Sub-Decree on the Cancellations and Reduction of Fishing Lots to be Reserved for Family Scale Fishing in Prey Veng Province	5 Mar 2007
Sub-Decree on the Cancellations and Reduction of Fishing Lots to be Reserved for Family Scale Fishing in Siem Reap Province	22 Jan 2001
Sub-Decree on the Cancellations and Reduction of Fishing Lots to be Reserved for Family Scale Fishing in Takeo Province	22 Jan 2001
Sub-Decree on Contract Farming Production	24 Feb 2011
Sub-Decree on the Establishment of Alternative Food Supplies System in Cambodia	12 Sep 2012
Sub-Decree on the Lease of Fresh Water and Sea Fishing Domains for Exploitation	9 May 1989
Proclamations	
Joint Declaration on the Illegal Fishery Record Form	15 Nov 2011
Prakas on Determination of Flooded Forest Areas as Fresh Water and Marine Fisheries Areas	7 Sep 1989
Prakas on the Establishment of Pine Tree and Ta Trav Tree Seed Source Areas in Kompong Thom Province	18 Oct 2004
Prakas on Launching Methods of Good Agricultural Practices (GAP) in Fruit and Vegetable Production	10 Mar 2010
Prakas on the Measurement to Manage and Eliminate Anarchy in Fisheries	5 May 1999
Prakas on Procedure for Acquiring Annual Forest Products and By-products Rights within Production Forest Not under Concession	18 Jul 2005
Prakas on the Classification and Management on the Aquarium Fish Species	3 Oct 2014
Prakas on the Communities Fisheries Registrations in Kampong Thom, Prey Veng, Kratie, Mondul Kiri, Ratanak Kiri and Kampot Provinces	14 Mar 2011
Prakas on the Establishment and Management of Forestry Community Zone in Koh Kong Province	19 Nov 2008
Prakas on the Establishment and Management of Forestry Community in Kompong Laeng District, Kompong Chhnang Province	19 Nov 2008
Prakas on the Establishment and Management of Forestry Community Zone in Oddar Meanchey Province	19 Nov 2008
Prakas on the Establishment and Management of Forestry Community Zone in Kompong Thom Province	10 Nov 2008
Prakas on the Establishment and Management of Forestry Community Zone in Banteay Meanchey Province	19 Nov 2008
Prakas on the Establishment of Kra Nhoung and Thnong Tree Seed Source Areas in Siem Reap Province	18 Oct 2004
Prakas on the Guidelines of the Community Fisheries	13 Jul 2007
Prakas on the Implementation for Contractor who Supply Rice for Export	19 Mar 2013
Prakas on the Implementation for the Contractors Who Supply Rice for Rice Exports	19 Mar 2014
Prakas on the Implementation of Import and Good Supplies	19 Mar 2014
Decisions	
Decision on the Establishment of the Inter-ministerial Committees to Prevent Anarchy of Fishery Crimes in Cambodia's Marine Fishing Areas	4 Apr 2000
Decision on the Limiting Marine Fishing Fee	5 Aug 2014

Source: (ODC 2016a)

4.4 Role of rice intensification policy and program

The Policy Paper on Paddy Production and Export Promotion was issued in 2010. It sets out the government's vision and strategy to transform Cambodia into a "rice basket", producing paddy surplus of 4 million tonnes and exporting 1 million tonnes of milled rice by 2015, and to gain international brand recognition for Cambodian rice (RGC 2010a). MAFF's action plan detailing the policy measures for implementing the Rice Policy Paper was issued in 2011. Twelve policy measures (three quick-win and nine medium and long-term) regarding paddy rice production, as follows (MAFF 2011).

Quick-win measures:

1. Streamline import procedures for rice seed, fertilisers, farm inputs and machinery
2. Provide tax incentives to encourage import of agricultural materials and equipment
3. Provide incentives for local seed producers and distributors.

Medium and long-term measures:

4. Devise long-term (10 to 20 year) water management plan detailing priority action steps and investments to upgrade irrigation schemes and water governance
5. Invest more in agricultural R&D stations and centres, crop trial sites for R&D, and technology transfer
6. Scale up commune-level agricultural extension services
7. Develop a plan for establishing farmer organisations, strengthening members' sense of ownership, and identifying local needs and issues
8. Facilitate smallholders and agricultural cooperatives' access to safe, formal financial services especially loans/credit
9. Develop land use zoning and distribute this information to farm households
10. Draft law on agricultural land use and management to ensure agricultural sustainability and improve land use efficiency
11. Carry out a countrywide agricultural census at 10-year intervals to create and update a land use map
12. Draft law on agricultural cooperatives and a sub decree on contract farming.

The main issues facing rice policy implementation relate to incentives/disincentives for increasing rice production, rice market stability/volatility, value chain performance/degree of linkages, and consumer/producer protection (UNDP 2013).

5. FOOD POLICY AND NUTRITION

5.1 Review of current food policy and food security

The 1996 World Food Summit definition of food security remains widely accepted and used even today: "Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life"(Olivier and Xinshen 2011). Most food policy is initiated at national level, and the concept of food security has been woven into many policies and programs ranging from ministry initiatives to NGO programs. As identified in the literature review, some policy interventions directly target food security issues while others are indirectly linked to promoting food security.

Cambodia's food security policies and programs are aligned with the core objectives set out in the national strategic framework. RS III, one of the top government policies, articulates strategic directions for food and nutrition security (FNS) and identifies policy priorities, focusing on agricultural intensification, land reform, sustainable natural resources management, health and nutrition and social safety nets (CARD 2014). Several ministries have launched multi-year strategic plans to address, directly or indirectly, the root causes of food insecurity. First, we look at direct policies. MAFF, through its Strategy on Agriculture and Water (SAW) 2006-2010, focused on food insecure rural households in rural areas. Two components of food security – intensifying and diversifying smallholder farming to build community self-reliance and reduce poverty, and improving institutional and policy framework and information management – formed the basis of FNS interventions under SAW. Other FNS programs built on SAW's food security pillar. The Ministry of Health, under the National Nutrition Program, has focused on tackling child and maternal malnutrition. Prepared under that program, the Fast Track Road Map for Improving Nutrition 2014-2020 builds on National Nutrition Strategy (NNS) 2009-2015 aiming to improve nutrition interventions delivered through the health sector. With approval from government and in collaboration with sector ministries and development partners, the Council for Agricultural and Rural Development (CARD) developed the National Social Protection Strategy (NSPS) 2009-2013 to promote human capital and provide protection for the poorest and most vulnerable against extreme poverty and hunger, livelihood shocks, vulnerability, exclusion and marginalisation. At that time, the main sources of vulnerability were food insecurity and child malnutrition.

A key policy that indirectly promotes FNS is the Policy Paper on the Promotion of Paddy and Rice Export. Although it was primarily developed to grab potentially greater benefits from increased global food demand and high prices on world markets, this rice promotion policy has played a very important role in highlighting potential risks to household food security. Another significant policy is the National Strategy for Rural Water Supply, Sanitation and Hygiene 2011-2025 which aims to improve rural people's access to safe water and sanitation and change hygiene/health attitudes. In the fisheries sector, actions under the Strategic Planning Framework for Fisheries 2010-2019 are expected to improve the food security and nutritional status of the poor and disadvantaged. The main objectives are to ensure the sustainable management of fisheries and fisheries resources and the conservation of fish habitats and biodiversity, promote aquaculture and fish processing, and improve local people's livelihoods as well as the nation's prosperity.

At international level, Article 11 of the International Covenant on Economic, Social and Cultural Rights recognises the right to adequate food and the right to freedom from hunger, and obligates parties to the Covenant to work together to eradicate hunger. Cambodia became a party to the Covenant in 1992. Embedded in Article 31 of The Constitution of the Kingdom of Cambodia, the Covenant requires government to make continuous progress towards realisation of these rights for all Cambodians. At regional level, the ASEAN Integrated Food Security Framework, developed and approved in 2008 in response to the 2007–08 food crisis, is supported by the Strategic Plan on Food Security 2009-2013. With the goal of achieving food security and improving farmer livelihoods across the region, the Framework aims to boost food production, reduce food losses at postharvest and processing, link small-scale farmers to produce and input markets, ensure food stability, make farm inputs widely available and accessible, and manage ASEAN's food emergency relief (CARD 2014). Another collaborative intergovernmental platform is Scaling Up Nutrition, which since its beginnings in 2009 has become a movement for action to improve maternal and child nutrition. It supports countries' efforts by lobbying to create political will, communicating best practices and providing resources.

In sum, strengthening household food security and nutritional status is a main aim of the development programs and projects implemented in Cambodia through the ministries of agriculture, water resources, rural development, health, and economy and finance, as well as local and international NGOs, development partners and the United Nations. The majority of programs are intended to resolve long-standing rural development problems and improve rural livelihoods, mainly focusing on smallholder and medium-scale farming, sustainable pro-poor economic growth, equitable access to and sustainable use of land and natural resources.

5.2 Review of national food supply

Improving food security for poor households in Cambodia requires that food availability and food access are integrated into policy at all levels across multiple sectors, from agriculture, fisheries, forestry, water resources and land use, to water sanitation and health, and education and training for employment and income generation. Food availability is related to national food supply, and is defined in the National Strategy for Food Security and Nutrition 2014-18 as "the ability to directly produce sufficient food to meet nutritional needs through own efforts in agricultural and livestock production and through gathering from common property resources (CPRs) including forests and fisheries" (RGC 2014, 5).

Table 19: Cambodia food balance sheet for rice in 2014/15

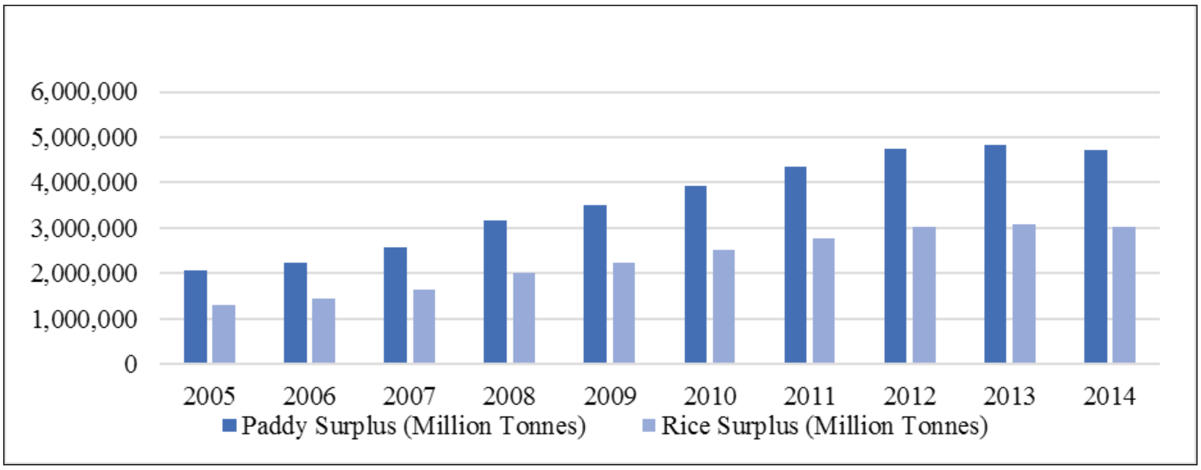
	Wet Season	Dry Season	Total
Cultivated area (ha)	2,564,572	490,935	3,055,507
Destroyed area (ha)	45,940	75	46,015
Replanted area (ha)	19,344	1	19,345
Harvested area (ha)	2,537,976	490,860	3,028,836
Yield (t/ha)	2.815	4.443	3.079
Paddy rice production (t)	7,143,521	2,180,896	9,324,416
Seed requirement and postharvest loss (13%) (t)			1,212,177
Remaining paddy for consumption (t)			8,112,239
Converted into milled rice (64% missing-rate) (t)			5,191,833
Food requirement (t/year)			2,178,050
National surplus production of rice (t)			3,013,783

Source: (MAFF 2015b)

The three supply-side dimensions of a country's macro-level food security are level of food production, stock levels and net trade (FAO 2008). At the micro-level, the food security of households and individuals is determined by their ability to produce their own food and/or to access (buy) food supply from the market. Importantly, their purchasing power is determined by both the cost of food and their sources of income, including remittances. Efforts to improve household food security therefore go hand-in-hand with efforts to intensify and diversify smallholder farming so that farmers not only produce food for their own consumption but also produce surplus to sell at market. Developing a more entrepreneurial culture among farmers would form a basis for the development of non-farm activities, jobs and incomes.

Figure 19 shows the year-on-year increases in paddy and milled rice surpluses between 2005 and 2013. Both milled rice and paddy surpluses dropped off slightly in 2014 because of drought during the wet season. Although Cambodia has become an important rice exporter, most paddy surplus is sold unprocessed immediately after harvest and slips over the border via informal trade routes to processors in Vietnam and Thailand. For stable food production, measures should be put in place to help smallholder and medium-scale farmers cope with the uncertainties they routinely face and to mitigate shocks caused by natural disasters (floods, droughts and storms), sudden output price drops and input price rises, and personal crises such as debt, unemployment and sickness.

Figure 19: Trends in national paddy and milled rice production surpluses 2005–2014



Source: (MAFF 2015b)

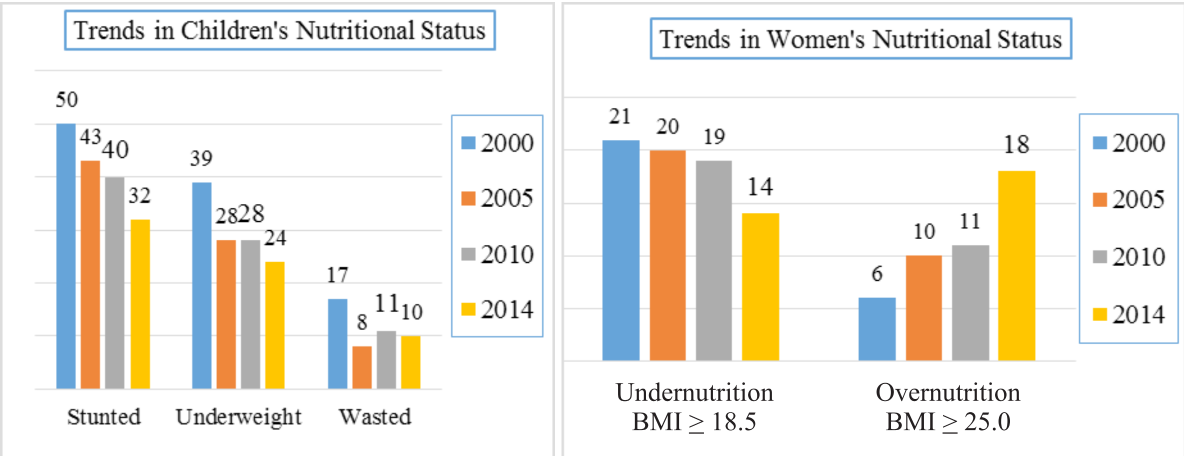
5.3 Review of nutritional status

Concomitantly with economic growth, increases in household income lead to higher nutrient intake and improved nutritional status. Equally, good nutrition is essential to building social capital and as such is a fundamental driver of socioeconomic growth and development at from country down to community level (Olivier and Xinshen 2011). In the context of food security, better nutrition must be achieved by strengthening social protection for vulnerable groups and finding solutions for temporary food shortages and external shocks. Macronutrient food intake in Cambodia has improved. In line with global trends, carbohydrate intake in Cambodia declined and fat and protein intake increased between 2004 and 2009, showing a better balanced diet. Even so, the daily diet of many Cambodians is short on micronutrients (CARD 2014).

The Technical Working Group on Food Security and Nutrition was established under the National Nutrition Strategy 2009-2015 to oversee specific programs and interventions; these included micronutrient supplementation schemes for infants and pregnant or breastfeeding women, mandatory fortification of salt with iodine, and the fortification of fish and soy sauce with iron. Following pilot tests, the third program was scaled up by the National Sub-committee for Food (FAO 2014). In addition, government supplied 30 hospitals with equipment for monitoring nutrition to tackle severe acute malnutrition and established guidelines on the management of acute malnutrition. Three indicators based on height, weight and age are used for measuring undernutrition in children under five years old; they are:

1. Rate of stunting (low height for age) reflects the cumulative effect of chronic or long term malnutrition.
2. Rate of underweight (low weight for age) indicates a combination of chronic and acute malnutrition.
3. Rate of wasting (low weight for height) indicates acute malnutrition.

Figure 20: Trends in children and women' nutritional status, 2000–2014



(CDHS 2014)

Figure 20 shows that between 2000 and 2014 the percentage of stunted children under 5 years old steadily declined from 50 percent to 32 percent (CDHS 2014). A glance at the trends in women's nutrition shows that one in seven were underweight in 2014 compared to one in five in 2000. Conversely, the percentage of overweight or obese women has gone up two-fold to 18 percent.

Looking at CDHS (2014) data on the prevalence of nutritional anaemia in Cambodia, over half (56 percent) of children aged 6-59 months are anaemic, of whom 30 percent have mild anaemia and 25 percent moderate anaemia. The prevalence of anaemia among this age group has stagnated since 2010. Among women in the 15-49 age group, 45 percent are anaemic the majority of whom have mild grade anaemia.

5.4 Existing food supply and nutrition gaps

The problem of securing a stable food supply continues to face many rural Cambodian households. First, using paddy yield per ha as a measure of performance can mask the low productivity and extreme vulnerability of smallholder farmers and, to an extent, has been a root cause of their neglect or marginalisation, even in rice intensification programs designed to benefit them. Adding to an already difficult situation are slow scaling up of rice intensification, ongoing storage problems in rice mills, persistent constraints on market participation, low investment in R&D, and limited training and demonstrations to improve pre- and postharvest handling practices. A second challenge confronting food-insecure small-scale farmers concerns low farm diversification and weak or absent integration of production and marketing, underpinned by the limited scope of diversification programs and their poor coordination and monitoring, lack of farmer groups/organisations/cooperatives that leverage collective action for marketing and input supply, very slow-to-establish contract farming arrangements, and private sector reluctance to invest/engage in smallholder production. Third is the limited access of smallholder farmers to irrigation, who tend to be marginalised in large-scale irrigation schemes.

An overriding issue is limited or restricted access to farmland, the main asset for improving household productivity. Limited access to land stems from weak or unsecured community land rights especially in areas with ethnic minority populations, growing land pressures and expansion of farming into marginal areas in the lowlands, limited access of the land poor to social land concessions and agricultural services, lack of legal framework for land management and conservation. The degradation of and limited access to fisheries and forest resources also jeopardise the food security of poor households: community co-management of natural resources has so far not realised its promise because projects have been small-scale and momentum tends to cease when support stops, economic land concessions have encroached on communal lands either cutting off or restricting local people's access to common property resources, hydropower dam development has blocked fish migration routes and harmful fishing practices have depleted fish stocks. In addition food security-related social protection interventions are often project based, ad hoc and not at scale. The consequent increasing use of negative coping mechanisms in times of natural disaster, economic crisis or shocks further weakens the stability of food supply among vulnerable households. Lastly, climate change is expected to have far reaching impacts on food production and natural resources and will affect all dimensions of household food security.

Although some health indicators suggest steady progress, Cambodia still has very high rates of child and maternal malnutrition. Indeed, improvements in child and maternal malnutrition have stagnated, according to CARD (2014). This is because health sector nutrition interventions are not yet at scale and nutrition education is insufficiently mainstreamed. Poor sanitation and hygiene practices among poor rural households are associated with stunting and malnutrition, and indicate a gap or insufficient linkages between WASH (water, sanitation and hygiene) and nutrition programs. Food fortification is a cost-effective way of preventing micronutrient deficiencies, yet Cambodia still lacks comprehensive national policy and guidelines in this regard. Further, a countrywide large-scale community-based nutrition program has yet to be developed. Thus community-based approaches to improve nutrition have been piecemeal and opportunities for improving nutrition have not been scaled up. The last nutrition gap is limited access to nutrition services by poor households caused by insufficient linkages between nutrition programs delivered by the health sector and social protection programs.

6. FUTURE OF AGRICULTURE IN CAMBODIA

Agriculture and its sectors will continue to provide stability and contribute significantly in Cambodia's pursuit of inclusive economic growth and sustainable agricultural and rural development, with equity, resilience and food security as crosscutting goals. As stated in the Agricultural Sector Strategic Development Plan 2014-18, the overall goal is to "increase agricultural growth to around 5 percent per annum through enhancement of the agricultural productivity, diversification and commercialization and livestock and aquaculture farming by taking into account… sustainable forestry and fisheries resource management" (MAFF 2015a). To that end, government has geared recent efforts towards modernising agriculture, with distinct shifts in approach, scope and pace to move production systems from extensive to intensive farming.[1] Simultaneously, efforts to promote an entrepreneurial culture among smallholder and medium-scale farmers should lead to further commercialisation, which is expected to raise farm incomes, improve farm welfare and, ultimately, reduce rural poverty. Government intends to achieve and maintain agricultural growth targets by strengthening and expanding extension services and market information with a view to improving agricultural methods and crop productivity. With widespread extension services, government agencies can readily convey up-to-date information about new seed varieties, seed production techniques and farming methods, foster local innovations and kick-start commercialisation. Then, at a l stage, government can use those same channels to promote R&D for productivity improvement and human resource training and development. Identified as both an area where Cambodia has a potential comparative advantage and a strategic area for development, the rice sector will continue to benefit from special attention under the Rice Policy Paper 2011-20. Moreover, value added in crop production is expected to rise to USD1450/ha in 2018 (RGC 2015). Meanwhile, obligations established under agricultural land law and codes of conduct should improve adherence to sustainable agricultural practices.

Table 20: Key proposed indicators for agriculture, 2016-18

Key Indicators	Unit	2016	2017	2018
Yield	tonnes/ha	3.21	3.23	3.25
Cultivated area (paddy)	million ha	3.2	3.28	3.34
Rice production	million tonnes	10.28	10.56	10.85
Paddy surplus	million tonnes	5.6	5.79	6.00
Area under all crops (incl. permanent crops and plantations)	million ha	5.23	5.44	5.65
Agricultural communities	number	675	775	875
All types of animal production (+3%)	million head	38.03	39.17	40.34
Aquaculture (15% increased)	tonnes	129,400	148,800	171,170

Source: (RGC 2015)

The ability to strengthen food security, defined as availability, access to and use of food, and improve the quality of nutrition in Cambodia requires coordinated actions across multiple sectors. As set out in the National Strategy for Food Security and Nutrition (NSFSN) 2014-18, the goal is that "by 2018, Cambodians will have substantially improved physical, social and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food

1 "Extensive stage" typically involves greater use of available agricultural resources (e.g. land and water) and traditional inputs. "Intensive" stage typically involves adoption of new methods and technologies, R&D, farm mechanisation and improved irrigation, all of which help improve productivity and diversification into high value.

preferences and optimize the utilization of this food to keep a healthy and productive life" (CARD 2014, 3).

Table 21: Key indicators of nutrition

Key Indicators	2010	2016	2017	2018
% of children aged 0-59 months who are moderately or severely stunted (height for age < - 2SD)	39.9	-	-	25
% of children aged 0-59 months who are moderately or severely underweight (weight for age < - 2SD)	28.3	-	-	19
% of children aged 0-59 months who are moderately or severely underweight (weight for height < - 2SD)	10.9	9	8	7
% of women aged 15-49 years with BMI<18.5kg/sq. meter	19.1	8	7	7
Proportion of population below the food poverty line (%)	3.8	<5	<5	<5
Average food consumption (kcal/person/day) among poorest quintile (according to household estimation)	1690	1944	2002	2060
% of children aged 6-59 months with anaemia	55.1	40	38	36
% of women aged 15-49 years with anaemia	44.4	34	32	30
% of pregnant women with anaemia	52.7	44	42	40
% of women overweight with BMI>25kg/sq. meter	6	<15	<15	<15

Source: CARD 2014

Under the NSFSN, it is expected that by the end of 2018 the prevalence of chronic malnutrition and underweight among children aged 0-59 months who are moderately or severely stunted will have declined to 25 percent, the incidence of undernourishment among women (age 15-49 years) will have dropped to 6 percent and of their overnutrition kept to below 15 percent , average daily per capita food consumption among the poorest quintile will have risen to 2060 kcals and the quality of their food intake significantly improved (CARD 2014). The NSFSN has identified three objectives and key actions to achieve them, as follows:

1. Increase food availability and food access among food-insecure households through more productive and diversified crop and livestock farming, fisheries and forest resource collection, and through non-farm jobs and wages.
2. Improve the general population's use of their food with a view to reducing child and maternal malnutrition and enhancing human and economic development.
3. Increase food supply stability among poor and vulnerable households by putting in place food security-related social protection measures and building their capacities to cope with risks and shocks (CARD 2014, 3).

In terms of institutional arrangements, NSFSN implementation, and by implication enhancing food security and nutrition, is the responsibility of line ministries and decentralised government institutions.

7. METHOD

The research used a combined quantitative and case study approach. There were seven steps within the quantitative approach, as follows:

1. Calculation of current food supply
2. Estimation of nutritional supply (protein, calories, lysine)
3. Projection of potential area for irrigated double rice cropping
4. Scenario design and modelling of three farming systems
5. Estimation of average yields by food type for each scenario
6. Estimation of water requirements in the potential area for each scenario
7. Estimation of energy requirements in the potential area for each scenario.

Scenario analysis synthesised a variety of secondary data to estimate and compare food and nutritional supplies, yields, water and energy 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 best practices for rice (system of rice intensification), ricefield fish (community fish refuges) and high-yield vegetable production.

7.1 Data sources

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) and vegetable yield (1996-2015) (MAFF, 2016). Milled rice supply per hectare was calculated based on figures from MAFF Annual Report 2008-09 (MAFF 2010b).

FAO (2016a) database was used to calculate current food supply of paddy, vegetables and bovines, as follows: (1) paddy harvest area, import, export, stock, feed, seed, food manufacture, waste and other use; (2) vegetables harvest area, import, export, stock and waste; and (3) bovine meat production, import, export, stock, permanent meadow and pasture area.

To estimate ricefield fish supply, the study used two sets of data: The first estimation was based on MAFF (2016), and the second on data compiled from six studies done in various parts of Cambodia: Gregory, Guttman, and Kekputhearith (1996), Nesbitt (1997), Guttman (1999), Troeung et al. (2003), Hortle, Troeung, and Lieng (2008) and Thouk (2009). Data on OAA yield came from Hortle, Troeung, and Lieng (2008) and Gregory, Guttman, and Kekputhearith (1996).

Estimations of nutritional supply of protein, calories and lysine were calculated using FAO's Food Composition Tables (FAO 1953, 1981), Mulia et al. (2010) and Pittock, Dumaresq, and Orr (2015). The potential area for rice double cropping was determined using a crop map from IRRA (2010) and a rice map from Open Development Cambodia (2015). Finally, water use estimation was based on Abrams (2015); energy consumption estimation for rice production per hectare used Islam et al. (2011) and for vegetables Canakci et al. (2005).

Case study material on SRI adoption was drawn from (Tech 2014) and a survey (Anthofer et al. 2004), and on CPR adoption from USAID's Rice Field Fisheries Enhancement Project 2012-16 (USAID 2017) and doctoral research (Thouk 2009) on lowland ricefield fishery. Data on model vegetable farmers was not available, so the study used MAFF (2016) data on the highest vegetable yields produced in 2015.

7.2 Calculations, estimations and simulation

Food supply calculation. To calculate the different types of food supplies, seven formulae from FAO (2001) were adapted based on available data, as follows.

Formula A determines supplies of rice, bovine meat, ricefield fish, OAA and vegetables. Food supply is divided by harvest area to determine food supply per hectare.

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

Formula B calculates paddy supply per hectare using data on paddy yield and harvest area, as well as on import, export, stock, feed, seed, food manufacture, waste and other use.

$$\text{(B) Paddy supply per hectare} = \text{Yield} + \frac{\text{import} - \text{export} \pm \text{stock} - \text{feed} - \text{seed} - \text{food manufacture} - \text{waste} - \text{other use}}{\text{harvest area}}$$

Formula C for rice supply per hectare is based on MAFF (2010b) data indicating that 64 percent of available paddy is converted into milled rice.

(C) Rice supply per hectare = paddy supply per hectare * 0.64

Formula D to calculate bovine meat supply per hectare uses data on bovine meat production, import, export, stock, and permanent meadow and pasture area.

$$\text{(D) Bovine meat supply per hectare} = \frac{\text{production} + \text{import} - \text{export} \pm \text{stock}}{\text{permanent meadows and pastures area}}$$

Formula E either assumes that ricefield fish supply per hectare is equal to ricefield fish yield, or divides ricefield fish production by wet-season rice harvest area because available data include ricefield fish production, harvest area of wet-season rice and ricefield fish yeild. The formula was run with two sets of data: first with data from MAFF; second with data from six research studies in different areas of the country (see Appendix 11).

$$\text{(E) Ricefield fish supply per hectare} = \frac{\text{ricefield fish production}}{\text{harvest area of wet season rice}} \text{ Or ricefield fish yield}$$

For formula F, OAA supply per hectare is assumed to equal OAA yield.

(F) OAA supply per hectare = OAA yield

Formula G to calculate vegetable supply per hectare uses data for vegetable yield, import, export, stock, waste and harvest area.

$$\text{(G) Vegetable supply per hectare} = \text{yield} + \frac{\text{import} - \text{export} \pm \text{stock} - \text{waste}}{\text{harvest area}}$$

Nutritional supply estimation. The study relied mainly on FAO's (1953, 1981) food composition tables to estimate the nutritional supply per hectare of rice, bovine meat, ricefield fish, vegetables and OAA in terms of protein, calories and lysine (Table 22). However, these sources do not give specific information about the protein, calorie and lysine content of OAA, or the protein and lysine content of vegetables. We therefore turned to Mulia et al. (2010) for data on the nutritional content of the OAA listed in Table 23, but their study did not measure calorie content. To determine the calorific value, we first calculated the average protein and lysine content of OAA and then compared those figures with FAO (1981). The closest match was found to be crustacean (protein 16 g/100g and lysine 1,262 mg/100g); the corresponding calorific value was taken from FAO (1953). For vegetables, we used data on protein and lysine from Pittock, Dumaresq and Orr (2015).

Table 22: Average protein, calorie and lysine content by food type

Food stuff	Protein (g/100g)	Calories (kcals/100g)	Lysine (mg/100g)
Ricefield fish (all fish, unspecified)	18.80[a]	132[b]	1713[a]
OAA	16.00[a]	103[b]	1262[a]
Bovine (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[c]	27[b]	100[c]

Sources: [a] (FAO 1981); [b] (FAO 1953); [c] (Pittock, Dumaresq, and Orr 2015)

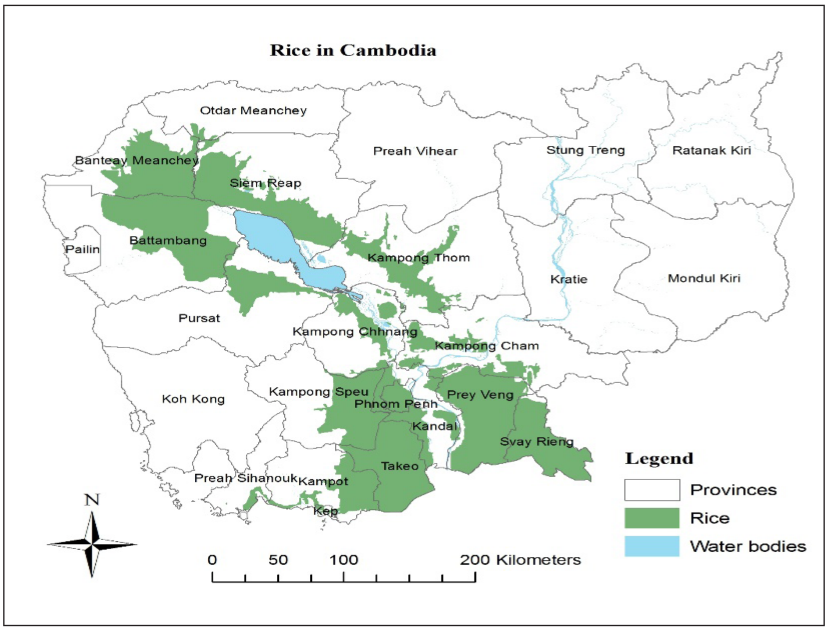
Table 23: Average protein and lysine content of OAA

OAA	Protein (g/100g)	Lysine (mg/100g)
Snakehead murrel	18.60	1637.00
Freshwater crab	16.30	591.20
Small apple snail	13.00	772.10
Golden apple snail	11.60	641.30
Big apple snail	11.80	528.10
Chinese edible frog	17.30	1284.00
Cricket	25.10	1173.00
Average	16.24	946.67

Source: (Mulia et al. 2010)

Potential production area projection. Using Arc-GIS, the current irrigated single-crop rice area was chosen as the potential area for irrigated double rice cropping.

Figure 21: Rice map of Cambodia



Source: (ODC 2015)

Scenario modelling. Three scenarios were designed to compare current food supply (in term of protein, calories and lysine), food production projection (in term of protein, calories and lysine), water use and energy consumption in the potential production area under three farming systems, as follows:

Scenario 1: double rice cropping (wet-reason rice 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 because it reflects conventional agricultural intensification. The other two scenarios were chosen 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. The scenarios were run a second time in order to compare the same criteria with and without the adoption and uptake of best practices and new techniques.

Yield estimation. Average yields of dry-season rice, wet-season rice, vegetables, bovine meat, ricefield fish and OAA in terms of protein, calories and lysine were estimated for the three scenarios.

Water use estimation. Figures from Abrams (2015) were used to estimate water consumption in the three scenarios. Currently, the volume of water used for agriculture in Cambodia is 2.053 km^3. A single rice crop on one hectare needs about 12,000 m^3 of water, and vegetable crops (6 months/year) need 7,500 m$^{3/}$ha.

Energy consumption estimation. Energy consumption for rice production per hectare was estimated using data from a study by Islam et al. (2011) which examines energy use under different tillage options: conventional tillage and puddling, puddling and manual forming of beds, 58 cm dry bed formed by VMP (Versatile Multi-crop Planter) in a single pass, and dry strip tillage by VMP in a single pass. Conventional tillage and puddling was chosen for this study because it fits the situation in Cambodia. Total energy consumption for rice using conventional tillage and puddling is 26,750 MJ/ha (Table 24). Estimated energy consumption for vegetables of 61,211 MJ/ha was taken from Canakci et al. (2005).

Table 24: Energy consumption (MJ/ha) for rice

Conventional tillage and puddling		
	MJ/ha	% of total
Direct energy		
Fuel	2200	8.2
Human	160	0.6
Subtotal	2350	8.8
Indirect energy		
Seeding	440	1.6
Machinery	4390	16.4
Fertiliser application	9930	37.1
Plant protection	3930	14.7
Irrigation	5710	21.3
Subtotal	24400	91.2
Total	26750	100.0

Source: Adapted from (Islam et al. 2011)

7.3 Data limitations

Lack of available data meant that it was not feasible to apply the FAO (2001) formulae in their entirety.

- Formula B: Paddy supply was calculated from 2005 to 2011 because other use data of paddy was available from 2005 to 2011.
- Formula D: Bovine meat data of feed, seed, food manufacture, waste, other use were unavailable, these elements were assumed equal zero to calculate average of bovine meat supply
- Formula E: Ricefield fish data of import, export, stock, feed, seed, food manufacture, waste, other use were unavailable, these elements were assumed equal zero to calculate average of ricefield fish supply
- Formula F: OAAs data of production, import, export, stock, feed, seed, food manufacture, waste, other use were unavailable, these elements were assumed equal zero to calculate average of OAAs supply
- Formula G: Vegetable data of feed, seed, food manufacture, other use were unavailable, these elements were assumed equal zero to calculate average of vegetable supply

8. RESULTS

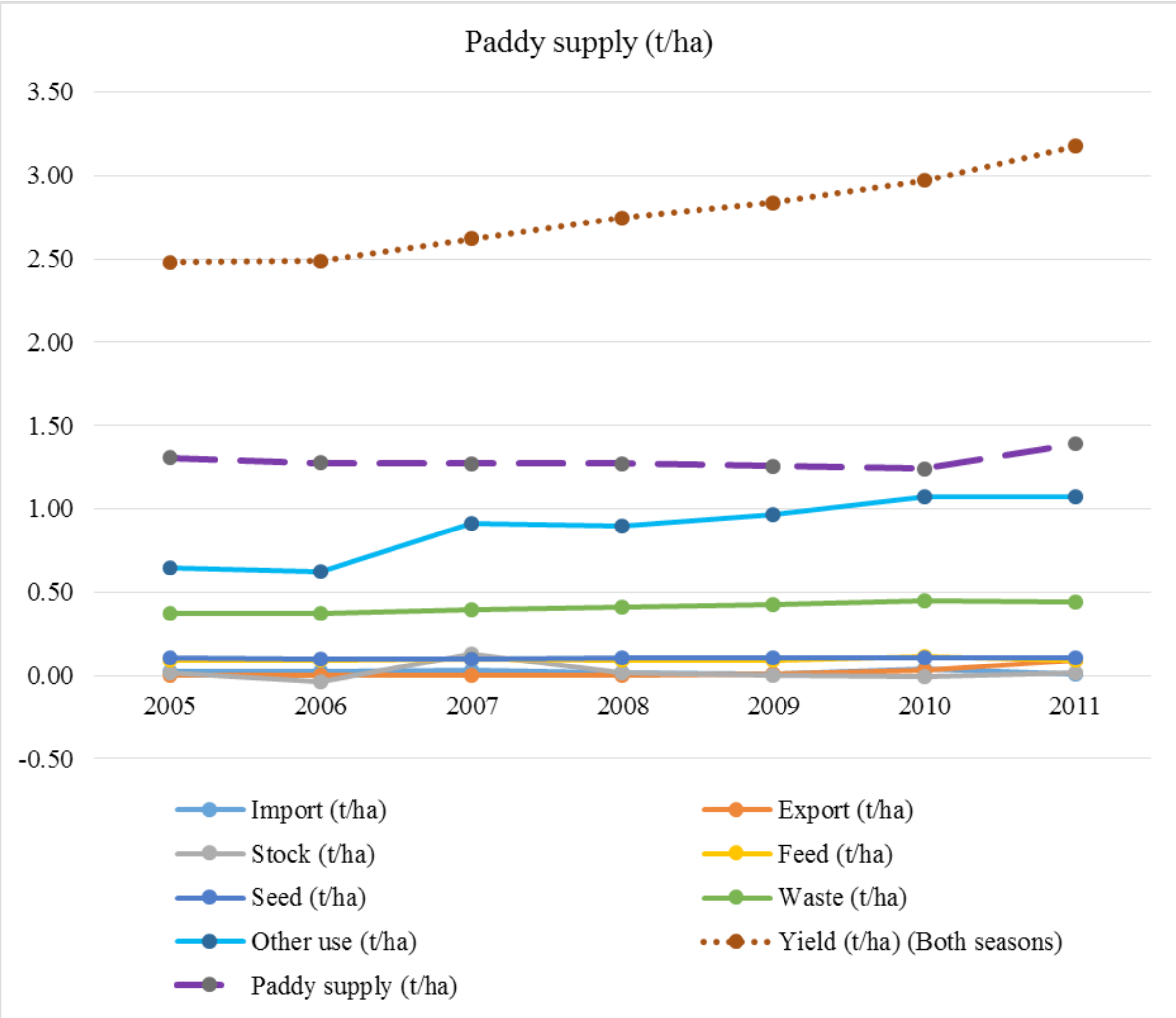
The results are divided into five sections. First we present estimates of current food supplies per hectare, followed by projections for food supply, food production, water use and energy consumption under three scenarios – double rice cropping, rice-fish-OAA-bovines, rice-fish-OAA-vegetables.

8.1 Estimated food supply per hectare in terms of protein, calories and lysine

8.1.1 Rice

Paddy supply per hectare (Formula B) is calculated based on ten elements: yield, import, export, stock, feed, seed, food manufacture, waste, other use and harvest area. We calculated supplies for the period 2005 to 2011 because data on "other use" of paddy was only available for those years. Figure 22 shows that paddy supply increased in 2011 because paddy yield increased (paddy production increased and harvest area expanded).

Figure 22: Trends in paddy supply per ha, 2005-2011

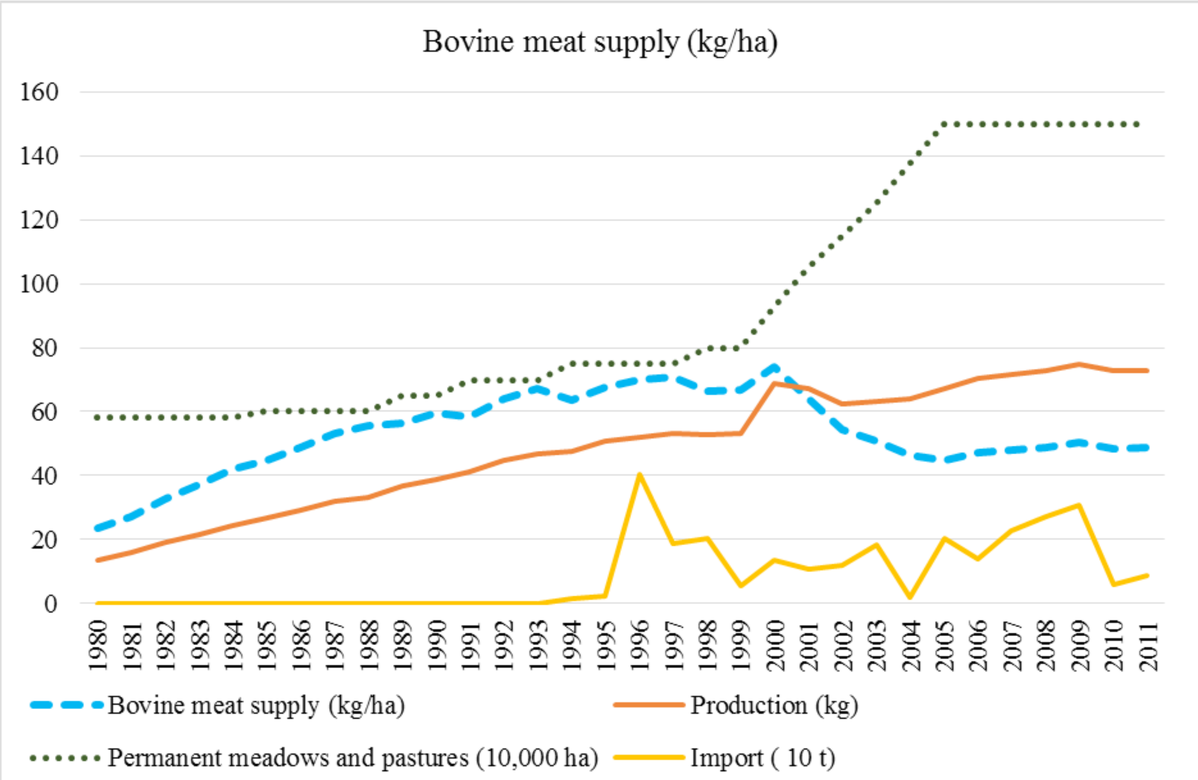


Trends of protein, calories and lysine from rice supply depend on paddy supply. The average rice supply for 2005-2011 of 0.86 t/ha provides protein of about 0.06 t/ha, calories of about 3,070 kcals/ha and lysine of about 0.003 t/ha (Figure 26).

8.1.2 Bovine meat

The calculation for per hectare bovine meat supply (Formula D) is based on five elements: production, import, export, stock, permanent meadow and pasture area because data of other elements are not available. Figure 23 shows an increasing trend from 1980 to 2000, followed by a five-year decline and then a levelling off, reflecting expansion of permanent meadow and pasture. However, per hectare bovine meat production shows a more or less steady increase over the period 1980 to 2011.

Figure 23: Trend of bovine meat supply per ha, 1980-2011

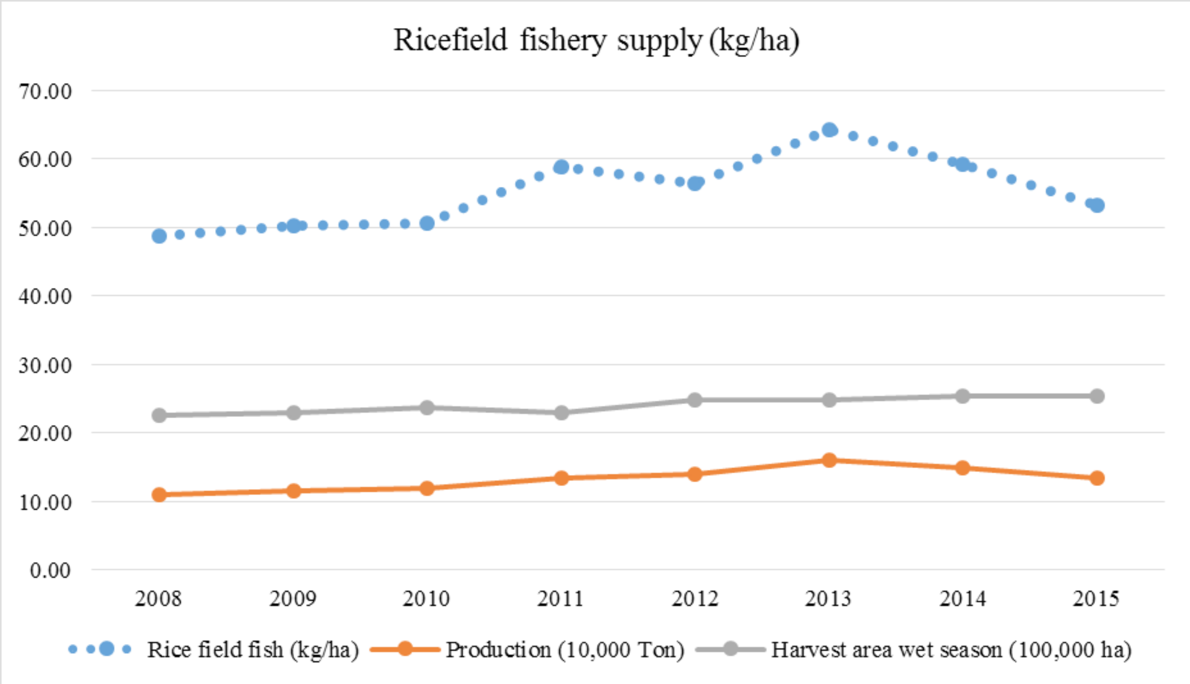


Trends of protein, calorie and lysine from bovine meat depend on bovine meat supply. Average bovine meat supply for 1980-2011 is 0.05 t/ha, providing protein of about 0.01 t/ha, calories of about 140 kcals/ha and lysine of about 0.001 t/ha (Appendix 5).

8.1.3 Ricefield fish

Ricefield fish supply per hectare (Formula E) is based on two elements: fish production and wet-season rice harvest area. Figure 24 shows that ricefield fish production between 2008 and 2015 is highest in 2013. This coincides with the implementation in 2012 of a five-year USAID-funded ricefield fisheries enhancement project. The project's objective is "To develop improved sustainable rice field fishery management practices mainly for poor aquatic resource dependent households" (World Fish 2016, 1).

Figure 24: Trend of ricefield fish supply per ha, 2008-2015



Tables 25 and 26 show two sets of calculations for trends in the protein, calorie and lysine yields of ricefield fish supply. The figures in Table 25 are based on data from MAFF (2016) for the period 2008 to 2015. Average ricefield fish supply is 0.06 t/ha, providing protein of about 0.01 t/ha, calories of about 70 kcals/ha and lysine of about 0.001 t/ha.

Table 25: Result 1 for ricefield fish supply per ha in protein, calories and lysine, 2008-2015

Year	Rice fieldfish supply (t/ha)	Protein (t/ha)	Calories ('000 kcals/ha)	Lysine (t/ha)
2008	0.05	0.009	0.06	0.0008
2009	0.05	0.009	0.07	0.0009
2010	0.05	0.010	0.07	0.0009
2011	0.06	0.011	0.08	0.0010
2012	0.06	0.011	0.07	0.0010
2013	0.06	0.012	0.08	0.0011
2014	0.06	0.011	0.08	0.0010
2015	0.05	0.010	0.07	0.0009
Average	0.06	0.010	0.07	0.0009

Note: No data of other elements, ricefield fish supply per hectare equals ricefield fish production divided by wet-season rice harvest area. Source: data from MAFF 2016

The figures in Table 26 were calculated using data from five studies. Average ricefield fish supply is 0.12 t/ha, providing protein of 0.02 t/ha, calories of about 150 kcals/ha and lysine of about 0.002 t/ha. These values for ricefield fish supply are double those calculated using MAFF (2016) data.

Table 26: Result 2 for ricefield fish supply per ha in protein, calories and lysine

Data source	Ricefield fish yield (kg/ha/ year)	Ricefield fish supply (t/ha/ year)	Protein (t/ha)	Calories ('000 kcals/ ha)	Lysine (t/ha)
Gregory et al. 1996	102.5	0.10	0.02	0.14	0.002
Nesbitt 1997	200-400	0.30	0.06	0.40	0.005
Guttman 1999	50-100	0.08	0.01	0.10	0.001
Troeung et al. 2003	55	0.06	0.01	0.07	0.001
Hortle et al. 2008	90.44	0.09	0.02	0.12	0.002
Thouk 2009	50-100	0.08	0.01	0.10	0.001
Average		0.12	0.02	0.15	0.002

Note: No data of other elements, ricefield fish supply per hectare equals ricefield fish production divided by wet-season rice harvest area or equal rice field fish yield

8.1.4 Other aquatic animals

Table 27 shows the average yearly protein, calorie and lysine supply from OAA (Formula F). The average OAA supply is 25.53 kg/ha, yielding protein of about 0.004 t/ha, 26 kcals/ha and lysine of 0.0003 t/ha.

Table 27: OAA supply in protein, calories and lysine

Data source	OAA supply (kg/ha)	Protein (t/ha)	Calories ('000 kals/ha)	Lysine (t/ha)
MRC 2008	28.56	0.005	0.029	0.0004
Gregory et al. 1996	22.50	0.004	0.023	0.0003
Average	25.53	0.004	0.026	0.0003

Note: No data of other elements, OAA supply per hectare equals OAA yield.

8.1.5 Vegetables

Vegetable supply per hectare (Formula G) was calculated based on six elements: vegetable yield, import, export, stock, waste, and harvest area because data of other elements are not available. Figure 25 shows that vegetable supply per hectare increased between 2008 and 2011, reflecting increased vegetable yield and production. Vegetable production may have increased because of the training and support farmers received under the USAID-funded project called Helping Address Rural Vulnerabilities and Ecosystem Stability (Cambodia HARVEST) 2011-16. The goal of this project is "to improve food security; strengthen natural resource management and resilience to climate change; and increase the capacity of the public and private sectors and civil society to support agricultural competitiveness" (USAID, 2017). Its specific objectives are to "increase incomes for 100,000 rural households; accrue economic benefits for 283,500 people; develop income-generating activities for 8,500 'extreme poor' households; diversify cropping systems for 56,000 households; and generate $40 million in incremental new agricultural sales" (USAID 2017). This project worked with 1,500 villages in four provinces: Battambang, Kampong Thom, Pursat and Siem Reap.

Figure 25: Trend of vegetables supply per ha, 1996-2011

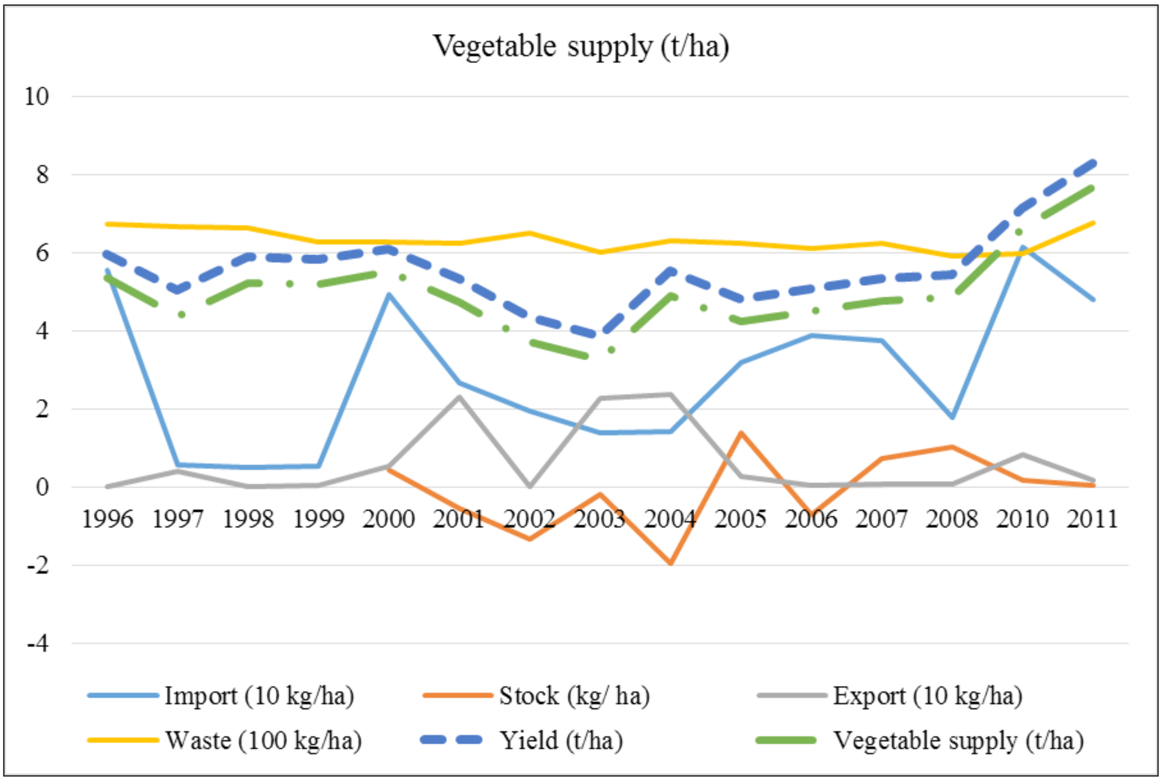


Figure 25 shows the trend of per hectare vegetable supply between 1996 and 2011. Average vegetable supply of 4.99 t/ha yielded protein of about 0.01 t/ha, calories of about 1,350 kcals/ha and lysine of about 0.005 t/ha (Appendix 6).

8.2 Current food supply per hectare in the three scenarios

In Scenario 1, dry-season and wet-season rice crops are grown. Total annual rice crops protein of about 0.12 t/ha, about 5,880 kcals/ha and lysine of about 0.005 t/ha (Table 38).

Table 28: Total annual supply per hectare of protein, calories and lysine in scenario 1

Food supply	Protein (t/ha)	Calories ('000 kcals/ha)	Lysine (t/ha)
Double rice crop	0.12	5.88	0.005

In Scenario 2, rice, fish and OAA are harvested from rice field in the wet season. After harvest, the rice areas are used for raising bovines. Table 29 presents two sets of results for average annual food supply per hectare because there are two sets of values for ricefield fish. The first set of results indicates total annual food supply of protein of about 0.09 t/ha, calories of about 3,146 kcals/ha and lysine about 0.005 t/ha. The second set of results indicates a slightly higher food supply per hectare yielding protein of about 0.1 t/ha, calories of about 3,256 kcals/ha and lysine of about 0.006 t/ha (Table 29).

Table 29: Total annual supply per hectare of protein, calories and lysine in scenario 2

Food supply	Protein (t/ha)	Calories ('000 kcals/ha)	Lysine (t/ha)
First result			
Rice	0.060	2.940	0.0020
Bovine	0.009	0.136	0.0010
Fish (based on MAFF data; see Table 25)	0.010	0.070	0.0010
OAA	0.004	0.030	0.0003
Total	0.090	3.180	0.0050
Second result			
Rice	0.060	2.940	0.0020
Bovine	0.009	0.136	0.0010
Fish (based on data from six studies; see Table 26)	0.020	0.150	0.0020
OAA	0.004	0.030	0.0003
Total	0.100	3.260	0.0060

In Scenario 3, rice, fish and OAA are harvested in the wet season. After harvest, the rice areas are used for growing vegetables. Again, there are two sets of results, reflecting the two sets of values for ricefield fish (see Tables 25 and 26). The first results listed in Table 30 indicate that total annual food supply per hectare provides protein of about 0.18 t/ha, calories of about 4,388 kcals/ha and lysine of about 0.009 t/ha. The second results show that total annual food supply per hectare yields protein of about 0.19 t/ha, about 4,469 kcals/ha and lysine of about 0.01 to/ha (see Table 30).

Table 30: Total supply per hectare of protein, calories and lysine in Scenario 3

Food supply	Protein (t/ha)	Calories ('000 kcals/ha)	Lysine (t/ha)
First result			
Rice	0.060	2.94	0.0020
Vegetables	0.100	1.35	0.0050
Fish (based on MAFF data; see Table 25)	0.010	0.07	0.0010
OAA	0.004	0.03	0.0003
Total	0.180	4.39	0.009
Second result			
Rice	0.060	2.94	0.0020
Vegetables	0.100	1.35	0.0050
Fish (based on data from six studies; see Table 26)	0.020	0.15	0.0020
OAA	0.004	0.03	0.0003
Total	0.190	4.47	0.0100

8.3 Projections for food products

This section presents the projected trends for food products rather than for food supplies. This is because of a lack of data to calculate food supply projections. The projections for food products were calculated based on the potential project area (ha) and food yields in terms of protein, calories and lysine. The estimates for protein, calories and lysine from rice, bovine meat, vegetables, ricefield fish and OAA yield are presented in Section 8.3.1. The projection for the potential area is shown in Section 8.3.2.

8.3.1 Estimates for protein, calorie and lysine yield

Rice. The average dry-season rice yield is 1.97 t/ha, which provides protein of 0.15 t/ha, calories of 7,030 kcals/ha and lysine of 0.005 t/ha. The average wet-season rice yield of 1.16 t/ha yields protein of 0.09 t/ha, calories of 4,130 kcals/ha and lysine of 0.003 t/ha (see Figures 26 to 28 and Appendix 8).

Bovine meat. Average bovine meat yield of 0.05 t/ha produces protein of about 0.01 t/ha, calories of 140 kcals/ha and lysine of 0.001 t/ha (see Figures 26 to 28 and Appendix 9).

Ricefield fish. The average ricefield fish yield per hectare and its average protein, calorie and lysine values are the same as for average ricefield fish supply per hectare in Tables 25 and 26.

OAA. Similarly to ricefield fish, average OAA yield and its average protein, calorie and lysine values are the same as for average OAA supply per hectare in Table 27.

Vegetables. The average yield of vegetables is 6.16 t/ha, and provides protein of 0.12 t/ha, calories of 1,660 kcals/ha and lysine 0.01 t/ha (see Figures 26 to 28 and Appendix 10).

Figure 26: Agriculture products in terms of protein yield

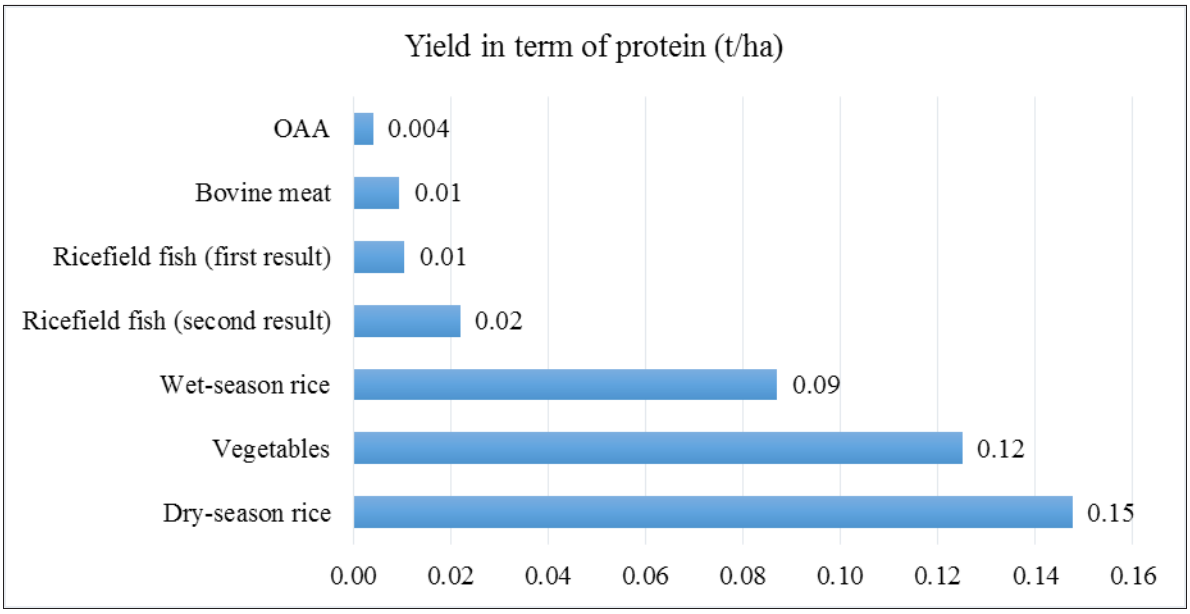


Figure 27: Agriculture products in terms of calories per hectare

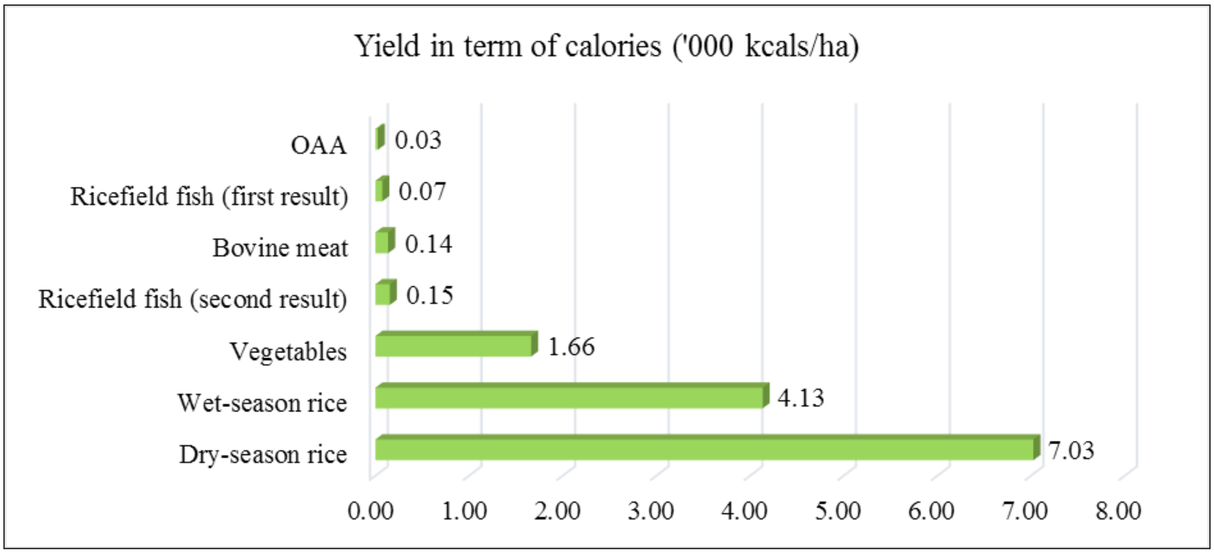


Figure 28: Agriculture products in terms of lysine per hectare

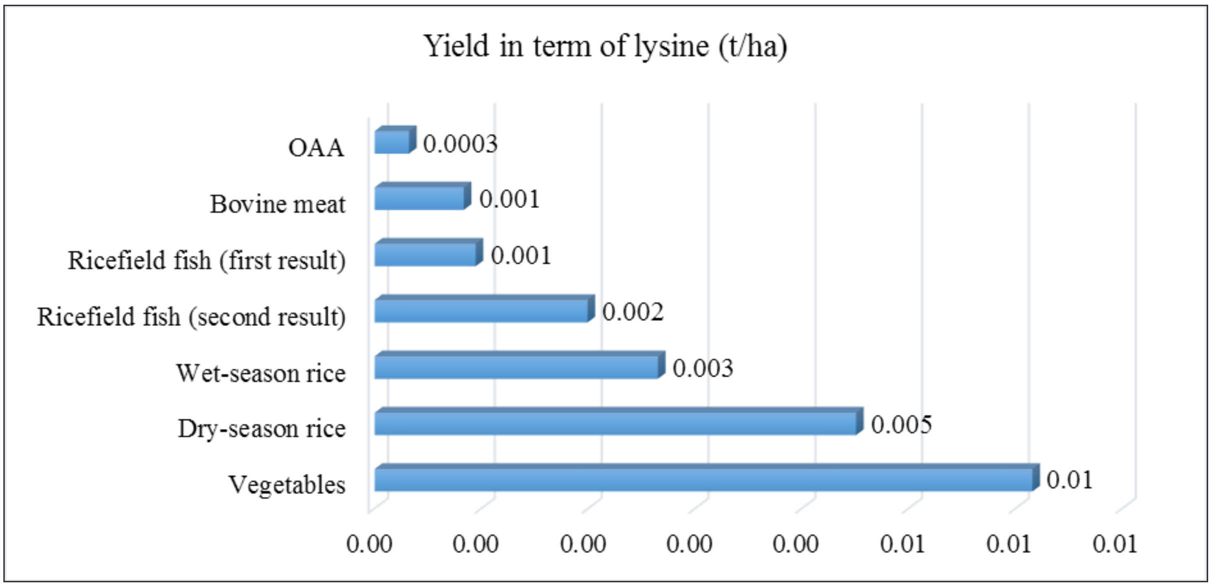
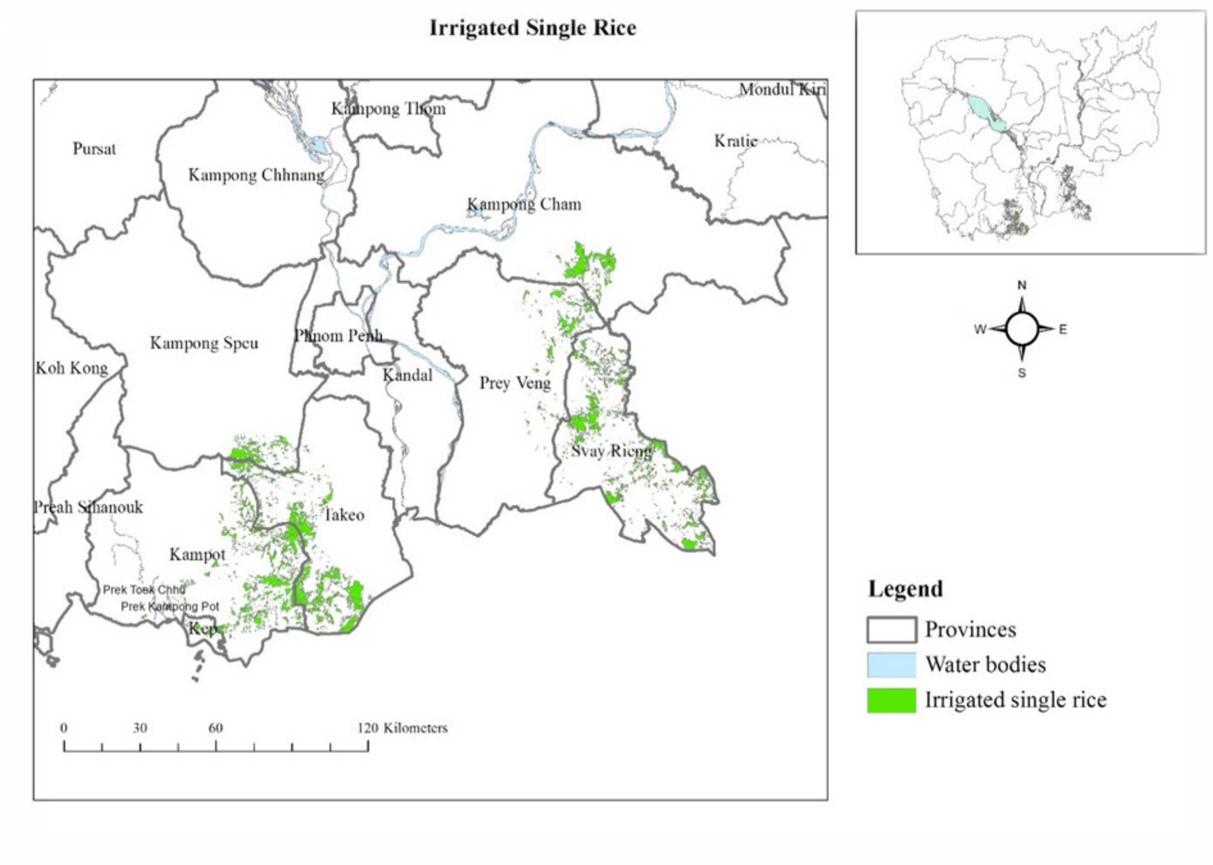


Figure 29 shows the current irrigated single rice crop areas that have potential for irrigated double rice cropping. Because the Master Plan for Irrigation System was not available, this study uses a crop map and a rice crop map (see Figures 14 and 21) to determine current irrigated single rice crop areas – a total area of 125,724 ha.

Figure 29: Potential area for irrigated double rice cropping



8.3.2 Food production projection for the three scenarios

Scenario 1. As Table 31 shows, if the irrigated single rice crop areas (125,724 ha) were converted to irrigated double rice cropping, the annual production of protein, calories and lysine from rice would double: protein would reach about 29.475 t/year, lysine about 900 t/year and calories about 1,403 million/year.

Table 31: Projections for protein, calorie and lysine production from rice in Scenario 1

Scenario 1	Protein (t/year)	Calories ('000 kcals/year)	Lysine (t/year)
Dry-season rice	18,556.07	883,268.84	566.58
Wet-season rice	10,920.03	519,793.22	333.42
Total	29,476.09	1,403,062.06	900.00

Scenario 2. Rice farming in the irrigated area (125,724 ha) is limited to a single wet-season crop grown in an integrated rice-fishery system that allows for the production of fish and OAA in the same rice field. After harvest, this area is used for raising cattle. Table 32 presents the projections for total protein, calorie and lysine production using the first (lower) result for ricefield fish yield: total production of protein is about 13,919 t/year, calories about 549 million/year and lysine about 597 t/year.

Table 32: Projections for protein, calorie and lysine supply in scenario 2 (first result using MAFF data from Table 25)

Scenario 2: First result	Protein (t/year)	Calories (‘000 kcals/year)	Lysine (t/year)
Wet-season rice	10,920.03	519,793.22	333.42
Bovine meat	1,180.69	17,076.60	104.93
Ricefield fish	1,304.77	9,161.18	118.89
OAA	513.56	3,306.03	40.51
Total	13,919.04	549,337.03	597.75

Table 33 presents the projections using the second (higher) result for ricefield fish yield. The projections for total protein, calories and lysine are higher than those based on the first result for ricefield fish yield. Total production of protein is about 15,363 t/year, calories about 559 million/year and lysine about 729 t/year.

Table 33: Projections for protein, calorie and lysine production in scenario 2 (second result using multiple data sources from Table 26)

Scenario 2: Second result	Protein (t/year)	Calories ('000 kcals/year)	Lysine (t/year)
Wet-season rice	10,920.03	519,793.22	333.42
Bovine meat	1,180.69	17,076.60	104.93
Ricefield fish	2,749.43	19,304.52	250.52
OAA	513.56	3,306.03	40.51
Total	15,363.70	559,480.36	729.38

Scenario 3. As in scenario 2, rice in the irrigated area (125,724 ha) is limited to a single wet-season crop grown in an integrated rice-fishery system. After harvest, this area is used for growing vegetables. Again, there are two sets of results reflecting the two sets of values for ricefield fish yield. Table 34 presents the projections for total protein, calorie and lysine production using the first result: total production of protein is about 28,453 t/year, calories 0.74 million/year and lysine about 1,267 t/year.

Table 34: Projections for protein, calorie and lysine production in scenario 3 (first result using MAFF data from Table 25)

Scenario 3: First result	Protein (t/year)	Calories ('000 kcals/year)	Lysine (t/year)
Wet-season rice	10,920.03	519,793.22	333.42
Ricefield fish	1,304.77	9,161.18	118.89
OAA	513.56	3,306.03	40.51
Vegetables	15,715.05	209,017.91	774.14
Total	28,453.41	741,278.34	1,266.96

Table 35 shows the projections using the second (higher) result for ricefield fish yield. The projections for protein, calorie and lysine production are higher than those based on the first result for ricefield fish yield. Total production of protein will reach about 29,898 t/year, calories about 751 million/year and lysine about 1,398 t/year.

Table 35: Projections for protein, calorie and lysine production in scenario 3 (second result using data from the literature in Table 26)

Scenario 3: Second result	Protein (t/year)	Calories ('000 kcals/year)	Lysine (t/year)
Wet-season rice	10,920.03	519,793.22	333.42
Ricefield fish	2,749.43	19,304.52	250.52
OAA	513.56	3,306.03	40.51
Vegetables	15,715.05	209,017.91	774.14
Total	29,898.06	751,421.68	1,398.59

8.4 Water use projection

Table 36 illustrates water requirements in the potential production area (125,724 ha) for all three scenarios. For scenario 1, about 3,017 MCM of water will be needed for irrigated double rice. The farming system in scenario 2 will need about 1,508 MCM of water, and that in scenario 3 will require about 2,451 MCM.

Table 36: Projections for water use requirements in the three scenarios

	Water use ('000 m3)
Scenario 1	3,017,376
Scenario 2	1,508,688
Scenario 3	2,451,618

8.5 Energy use projection

Table 37 shows energy requirements in the potential production area for all three scenarios. Irrigated double rice cropping in scenario 1 will require about 6,726 million MJ of energy. Agricultural production in scenario 2 will need about 3,363 million MJ of energy and in scenario 3 about 11,058 million MJ.

Table 37: Projections for energy requirements in the three scenarios

	Energy consumption ('000 MJ)
Scenario 1	6,726,234
Scenario 2	3,363,117
Scenario 3	11,058,809

9. DISCUSSION

In this section, we compare costs, benefits and risks under the three scenarios: (1) rice and rice, (2) rice, OAA, ricefield fish and bovines, and (3) rice, OAA, ricefield fish and vegetables. Of the two sets of results for scenarios 2 and 3, we discuss the second results (with the higher values for ricefield fish protein, calories and lysine) in both instances. Comparisons are made between all three scenarios of estimated current food supply per hectare, projected food production in terms of protein, calories and lysine from the potential area, and estimated water and energy requirements in the potential area. In addition, the results for each scenario are adjusted to model the highest attainable yields of rice, ricefield fish and vegetables as a result of agricultural extension/training and technology/best practice adoption, namely system of rice intensification (SRI) and community fish refuges (CFR). Lastly, the results for the three scenarios with and without training and best/practice technology adoption are compared.

9.1 Scenario 1: benefits, costs and risks

9.1.1 Benefits

Double rice cropping will generate more farm income from rice export, as "rice has played and will continue to play a strategic role in income growth, poverty reduction, and national and household food security" (Yu and Diao 2011, 1). Current food supply estimations per hectare and food supply projections for the potential area indicate that rice double cropping provides more calories than the other two farming systems. Current food supply per hectare in terms of calories equals about 132 percent of that in scenario 3 and about 181 percent of that in scenario 2. This means that one hectare in scenario 1 yields about 1,412 more calories than scenario 3 and about 2,625 more calories than scenario 2 (Table 38).

Table 38: Comparison of current food supply per hectare between the three scenarios

	Protein (t/ha/year)	Calories ('000 kcals/ha/year)	Lysine (t/ha/year)
Scenario 1	0.12	5.88	0.005
Scenario 2	0.10	3.26	0.006
Scenario 3	0.19	4.47	0.010
Scenario 1/Scenario 3 (%)	65.33%	131.60%	50.41%
Scenario 1/Scenario 2 (%)	127.20%	180.60%	87.75%
Scenario 2/Scenario 3 (%)	51.36%	72.87%	57.44%
Scenario 3 - Scenario 1	0.07	-1.41	0.005
Scenario 3 - Scenario 2	0.09	1.21	0.004
Scenario 1- Scenario 2	0.03	2.62	-0.001

Note: Second result of scenario 2 and 3 were chosen for represent the both scenarios because second result is higher than

Projected food production in terms of calories equals about 187 percent of that in scenario 3 and about 251 percent of that in scenario 2 (Table 39). This means that the potential production area in scenario 1 is projected to produce about 651 million more calories a year than scenario 3 and about 843 million more calories a year than scenario 2. This is significant because "rice is probably the most important grain with regards to human nutrition and caloric intake, providing more than one fifth of the calories consumed worldwide for humans" (Jirawut 2012, 2). Many people in Asia consume rice at every meal, but in countries such as Cambodia, Bangladesh and Myanmar, rice provides over 70 percent of most people's calorie intake. Finally, both estimates of current food supply and projections for food production indicate that scenario 1 provides the second highest supplies of protein. It also provides the second highest projections for food production of lysine (Tables 38 and 39).

Table 39: Comparison of food production between the three scenarios

	Protein (t)	Calories ('000 kcals)	Lysine (t)
Scenario 1	29,476.09	1,403,062.06	900.00
Scenario 2	15,363.70	559,480.36	729.38
Scenario 3	29,898.06	751,421.68	1,398.59
Scenario 1/Scenario 3 (%)	98.59%	186.72%	64.35%
Scenario 1/Scenario 2 (%)	191.86%	250.78%	123.39%
Scenario 2 /Scenario 3 (%)	51.39%	74.46%	52.15%
Scenario 1 - Scenario 2	14,112.39	843,581.69	170.62
Scenario 3 - Scenario 1	421.97	-651,640.38	498.59
Scenario 3 - Scenario 2	14,534.36	191,941.31	669.21

Note: Second result of scenario 2 and 3 were chosen for represent the both scenarios because second result is higher than

9.1.2 Costs

Energy costs are lower than in scenario 3 because scenario 1 uses less energy. The energy requirement is 61 percent lower than for scenario 3 and about 200 percent higher than for scenario 2. This means that, in a single year, the production area in scenario 1 requires about 3,363 million MJ more than scenario 2 but about 4,332 million MJ less than scenario 3 (Table 40).

Table 40: Comparison of energy requirements between the three scenarios

	Energy required ('000 MJ)
Scenario 1	6,726,234
Scenario 2	3,363,117
Scenario 3	11,058,809
Scenario 1/Scenario 3 (%)	60.82%
Scenario 1/Scenario 2 (%)	200.00%
Scenario 2/Scenario 3 (%)	30.41%
Scenario 1 - Scenario 2	3,363,117
Scenario 3 - Scenario 1	4,332,575
Scenario 3 - Scenario 2	7,695,692

Water costs are higher than in the other two scenarios because scenario 1 requires the highest volume of water (Table 41). Water requirements in scenario 2 equal 50 percent and in scenario 3 about 81 percent of that in scenario 1. This means that, in a single year, the potential production area requires about 1,508 MCM more water than scenario 2 and about 565 MCM more than scenario 3 (Table 41).

Fertiliser costs are second highest after scenario 3 because scenario 1 uses less fertiliser. A CDRI study Theng, Khiev, and Phon (2014) calculated the average fertiliser use in Cambodia between 2007 and 2013 to be about 204 kg/ha for dry-season rice and about 107 kg/ha for wet-season rice. Based on these averages, double rice cropping (dry and wet-season) on the potential production area of 125,724 ha would need 39,176 tonnes of fertiliser a year.

Expenditure on insecticides is less than in scenario 3. Farmers, on average, spend USD12/ha on spraying dry-season rice, about USD4/ha on wet-season rice and up to USD82/ha on vegetables (World Bank 2015). This means that the annual cost of applying insecticides to wet-season rice and dry-season rice in the potential production area is about USD2.01 million.

Labour costs are lower than in scenario 3 because scenario 1 needs less labour. In 2013, farmers needed 48.29 days of labour/ha for dry-season rice, 27.75 days/ha for wet-season rice and 169.85 days/ha for vegetables; the average cost of hired labour was USD4.56/day (World Bank 2015). Based on this data, annual labour costs in scenario 1 amount to USD43.59 million.

Table 41: Comparison of water requirements between the three scenarios

	Water use ('000 m3)
Scenario 1	3,017,376
Scenario 2	1,508,688
Scenario 3	2,451,618
Scenario 2/Scenario 1 (%)	50.00%
Scenario 2/Scenario 3 (%)	61.54%
Scenario 3/Scenario 1 (%)	81.25%
Scenario 1- Scenario 2	1,508,688
Scenario 1- Scenario 3	565,758
Scenario 3- Scenario 2	942,930

9.1.3 Risks

Rice double cropping requires important amounts of irrigation water. Therefore irrigation system or water supply costs need to be considered, not to mention the impacts of hydropower dams and climate change on water resources. The adverse effects of hydropower development on water quantity and quality in the Lower Mekong floodplains and the Tonle Sap system are well documented (Molle, Foran, and Floch 2009; MRCS/WUP-FIN 2007; Dugan 2008). Climate change, specifically the increasing frequency and intensity of floods and droughts (UNDP 2010), is expected to have significant effects on fresh water availability (UNDP 2011). Although ranked second for energy use after scenario 3, this scenario also requires substantial amounts of energy.

Agrochemicals pose health and environmental risks. The large inputs of fertiliser needed to grow two paddy crops a year can degrade soil quality (Bünemann and McNeill 2004). Long-term use or overuse of inorganic fertilisers can change soil chemistry and biology and have negative impacts on the soil ecosystem (Bunemann and McNeill 2004). A study on the effect of long-term fertiliser application (without addition of organic matter) showed "that the multiple nutrient deficiency problem suffered by the soils studied could be associated with soil acidity and nutrient imbalances. The other negative impact associated with acidification detected … is limitation on the availability of P in the soils" (Ogbodo 2013, 35). However, fertiliser-related risk in scenario 1 is lower than in scenario 3 because vegetable production requires higher amounts of fertiliser than rice. High pesticide use, especially on rice crops for export, can contaminate surface and ground water, soil, air, and non-target vegetation and organisms, which in turn affect food safety, ecosystem viability, and human and animal health (Aktar, Sengupta, and Chowdhury 2009).

Conventional agricultural intensification risks accelerating climate change effects. Expansion of double paddy production will increase methane (CH4) and nitrous oxide (N2O) emissions; these are potent greenhouse gases in terms of their global warming potential (GWP). A study in southern China to compare CH4 and N2O emissions between paddy and vegetable production with and without fertilisation concluded: "Land-use conversion from double rice cultivation to vegetables mitigated CH4 emissions but increased N2O fluxes. Fertilisation with N, P and K increased N2O fluxes under vegetables, but not under rice. In contrast, fertilisation had no effect on CH4 fluxes, regardless of land use practices. The GWP was lower under vegetables than rice when not fertilised, but not different between land uses when fertilised" (Yuan et al. 2016, 10). Therefore the GWP of scenario 1 is higher than that of scenario 3.

9.1.4. With agricultural extension – system of rice intensification methods

This section draws on case study data and looks at the costs, benefits and risks of double paddy production when farmers can access good support, training and new technologies. CEDAC, a well-known local NGO, introduced the system of rice intensification (SRI) into Cambodia. The initial assessment with 120 Cambodian farmers was done over three years from 2001 to 2003. Even with incomplete use of SRI practices, farmers managed to double their rice yields from 1.34 t/ha to 2.75 t/ha (Tech 2004). A prize-winning famer, Ms Nhem Sovannary, has worked with CEDAC since 2004. She first tried out SRI methods on 0.01 ha and achieved a yield of about 300 kg (3 t/ha), higher than the 2 t/ha she got using conventional practices on 1.4 ha land. In 2013, she came second out of 735 SRI farmers in a competition organised by CEDAC: using SRI methods, she had achieved a rice yield of about 7.33 t/ha. In 2014, she came third with a yield of 7.5 t/ha. She used no chemical inputs at all, instead enriching her land with compost from animal manure, biodigestate and crop residue (FAO 2017).

If SRI methods were adopted in the potential production area, projected food production in scenario 1 would increase: protein production would reach about 90,521 t/year, calories about 4,309 million kcals/year, and lysine about 2,764 t/year (Table 42).

Table 42: Projection of food production with SRI adaptation in Scenario 1

Scenario 1	Protein (t)	Calories ('000 kcals)	Lysine (t)
Rice (SRI adaptation)	45,260.64	2,154,406.46	1,381.96
Rice (SRI adaptation)	45,260.64	2,154,406.46	1,381.96
Total	90,521.28	4,308,812.93	2,763.92

SRI methods not only improve production but also increase soil water retention and reduce water consumption. Farmers did not measure the amount of water they used with SRI, but an evaluation by GTZ calculated that flooding during transplanting decreased from 96.3 percent before SRI to 2.5 percent afterwards, and soil moisture increased from 3.5 percent to 92.3 percent. During vegetative growth, permanent flooding decreased from 64.3 percent to 22.4 percent and alternate wetting and drying increased from 35.7 percent to 77.6 percent. GTZ concluded that paddy crops grown using SRI methods 1) use less water, 2) develop well although the ricefield is dry, and 3) are more resistant to drought (GTZ 2004). In a similar evaluation by CEDAC, farmers could not measure the amount of water they used, but they could compare the cost of water before and after adopting SRI. Before, farmers would spend 19,100 riels/ha on water, but in the second and third years after adopting SRI their average water costs were only 9,600 riels/ha. Specifically, before SRI, pumping water onto their fields used to cost farmers 13,700 riels/ha. This cost almost halved, dropping to 7,000 riels/ha, in the third year of SRI. CEDAC concluded that water use was reduced 50 percent while production and income roughly doubled. If SRI were adopted in the potential production area, double paddy crops would require about 1,509 MCM water (a decrease of 50 percent). SRI also reduces energy requirements for rice crops. As the case study illustrates, because SRI uses organic fertiliser, it can help mitigate potential risks from long-term use of inorganic fertilisers. Ogbodo (2013) also suggested that farmers could use organic manure and mineral fertilisers to correct soil fertility and improve productivity.

9.1.5 Summary

The benefits of double rice cropping are income from rice export, highest current food supply and food production of calorie, and second highest current food supply and food production of protein and second highest food production of lysine. However, water costs are the highest and energy, fertiliser, insecticide 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. Further, operating an irrigation system/water pumps consumes a substantial amount of energy, although total energy requirement is lower than in scenario 3. Alternative energy sources would need to be considered. 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 CH4 and N2O would increase under double paddy cropping; GWP would be higher than in scenario 3 with fertilisation, or the same as in scenario 3 with no fertilisation.

If SRI methods were practised, 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.

9.2 Scenario 2: benefits, costs and risks

9.2.1 Benefits

Among the three scenarios, scenario 2 provides the lowest current food supply per hectare and lowest food production in the potential area. For protein, one hectare of current food supply about 0.03 tonnes less than in scenario 1 and about 0.09 tonnes less than in scenario 3 (Table 38). This means that projected annual protein production in the potential area is about 14,112 tonnes less than in scenario 1 and about 14,534 tonnes less than in scenario 3. For calorie supply, one hectare of current food supply produces about 2,620 kcals less than scenario 1 and about 1,210 kcals less than scenario 3 (Table 38). Therefore projected annual calorie production in the potential area is about 843 million kcals less than for scenario 1 and about 192 million kcals less than for scenario 3. Per hectare lysine of current food supply is about 0.001 tonnes higher than in scenario 1 but about 0.004 tonnes lower than in scenario 3 (Table 38). Projected annual lysine production for the potential area is about 170.6 tonnes lower than in scenario 1 and about 669 tonnes lower than in scenario 3 (Table 39).

9.2.2 Costs

Scenario 2 has the lowest costs of all three scenarios because paddy is grown in the wet season and after harvest cows are left to graze on the rice fields. Water use is the lowest, requiring about 1,508 MCM less than scenario 1 and about 942 MCM less than scenario 3 (Table 41). Energy use is also the lowest, needing about 3,363 million MJ less than scenario 1 and about 7,695 million MJ less than scenario 3 (Table 40). Fertiliser consumption in the potential area is low at only 13,484 t/year, as is expenditure on insecticides of about USD503,000/year. Labour costs could not be fully estimated because there is no data on labour cost to raise bovines, but the labour cost to grow wet-season paddy is less than that of dry-season paddy in scenario 1 and vegetables in scenario 3. World Bank (2015) data indicates that in 2013 wet-season paddy required 27.75 days labour/ha, and the average cost of hired labour was USD4.56/day. So, based on this data, the annual labour cost for wet-season paddy in the potential area in scenario 2 would amount to about USD15.91 million.

9.2.3 Risks

Risks in scenario 2 are the same as in scenario 1, but the degree of risk is lower because water, energy, fertiliser and insecticide requirements are the lowest among the three scenarios.

9.2.4 With agricultural extension – community fish refuges

We draw on an empirical case study to discuss the costs, benefits and risks of integrated rice-fishery farming when farmers receive good support, training and new technologies, with a focus on community fish refuges (CFRs).

USAID funded a project called Rice Field Fisheries Enhancement from 2012 to 2016. The project sought “to improve sustainable rice field fishery management practices, mainly for poor aquatic-resource-dependent households” and promote “best practices in the establishment and management of CFRs to help achieve the Fisheries Administration’s target of 1,200 CFRs around the country” (Brooks and Sieu 2016, 5). By 2013, a total of 779 CFRs had been established in the country (Brooks and Sieu 2016, 5).

Box 1: About community fish refuges

A CFR [community fish refuge] is a form of stock enhancement or a fish conservation measure that is intended to improve the productivity of rice field fisheries. The idea behind refuge ponds is to create dry season refuges or sanctuaries for brood fish in seasonally inundated rice fields. Refuge ponds can be man-made ponds or natural ponds that can hold water throughout the year. During the dry season, these refuge ponds become disconnected from permanent natural water bodies. Then in the flood season, they are connected again to these water bodies or large seasonally flooded rice fields. The system takes advantage of the natural flood pulse. When the water level goes down in inundated rice fields, fish migrate to deeper areas, such as ponds, and stay there until the next flood season. During the flood season, these fish can emerge from the refuge ponds to spawn and feed on the inundated rice fields. (Joffre et al. 2012, 2)

The average yield with CFRs is 6.7 t/ha; the variability of yield per 100 m^2 is high (less than 10 kg/100 m^2 to more than 600 kg/100 m^2) (Brooks and Sieu 2016). If farmers were to adopt CFRs, ricefield fish production in the potential area of scenario 2 and 3 will increase to about 158,362 tons/year (production in term of protein), 1,112 million kcals/year (production in term of calories), and 14,429 tons/year (production in term of lysine) (Table 43). Improved total annual food production under scenario 2 in the potential production area would provide about 170,976 tonnes of protein, about 1,652 million calories and about 14,908 tonnes of lysine (Table 43).

Table 43: Projection of food production with CFR adaptation in Scenario 2

Scenario 2	Protein (t)	Calories ('000 kcals)	Lysine (t)
Wet-season rice	10,920.03	519,793.22	333.42
Bovine meat	1,180.69	17,076.60	104.93
Ricefield fish + CFR	158,361.95	1,111,903.06	14,429.47
OAA	513.56	3,306.03	40.51
Total	170,976.22	1,652,078.90	14,908.33

9.2.5 Summary

Based on current per hectare food supply estimations for the three scenarios, scenario 2 provides more lysine than scenario 1 but less than scenario 3. For lysine from projection of food production, scenario 2 less than scenario 1 and scenario 3, and the lowest amounts of protein and calories (from current food supply and food production projections for the potential area). 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 insecticide usage. If farmers were to adopt CFR, the projected production of protein, calories and lysine in the potential area would increase.

9.3 Scenario 3: costs, benefits and risks

9.3.1 Benefits

Looking at current food supply per hectare and food production projection in the potential area (Tables 38 and 39), among the three scenarios, scenario 3 provides the highest yields of protein and lysine and the second highest yield of calories. Current protein supply per hectare from rice, vegetables, ricefield fish and OAA in scenario 1 equals 65 percent, and in scenario 2 equals 51 percent, of that in scenario 3. This means that one hectare of current food supply in scenario 3 produces about 0.07 tonnes more protein a year than in scenario 1 and about 0.09 tonnes more than in scenario 2 (Table 38). Projected protein production in the potential area in scenario 1 equals 98 percent, and in scenario 2 equals 51 percent, of that in scenario 3. This means that annual protein production in scenario 3 is about 422 tonnes higher than in scenario 1 and about 14,534 tonnes higher than in scenario 2 (Table 39). Protein intake influences weight gain, growth and gestation (CAERT 2011). Together, the four different sources of protein produced in scenario 3 can help reduce stunting and underweight in Cambodia.

For lysine, current food supply per hectare in scenario 1 equals about 88 percent and in scenario 2 about 57 percent of that in scenario 3. This means that one hectare of current food supply about 0.005 tonnes more lysine a year than in scenario 1 and about 0.004 tonnes more than in scenario 2 (Table 38). Projected lysine production in the potential area in scenario 1 equals about 64 percent, and in scenario 2 about 52 percent, of that in scenario 3. This means that lysine of food production in scenario 3 is about 499 tonnes higher than in scenario 1 and about 669 tonnes higher than in scenario 2 (Table 39).

Third benefit, this scenario provide high calories in second rank from current food supply and food production projection (Table 38 and Table 39). Revenue from vegetables means that this scenario also generates the highest farm income. World Bank (2015) data indicates that the 2013 vegetable crop gross margin of USD1,394/ha was about 5.6 times higher than the wet-season rice gross margin (USD245/ha) and about 4.7 times higher than the dry-season rice gross margin (USD296/ha). It was also higher than the gross margins of cassava and maize. This scenario can provide fresh vegetables to meet domestic demand. FAO import data shows that vegetable imports more than doubled in just one year, from 4,040 tonnes in 2012 to 8,545 tonnes in 2013. Moreover, in February 2016, the VOV website reported that "Cambodia annually imports around 100,000 tonnes of fresh vegetables worth roughly USD200 million from Vietnam, Laos and Thailand", and that Vietnam has been shipping fresh vegetables to Cambodia since 2009, increasing from 200 t/day to more than 300 t/day in early 2016.

9.3.2 Costs

Energy, fertiliser, insecticide and labour costs in scenario 3 are the highest among the three scenarios, and water costs are the second highest after scenario 1. The energy requirement of scenario 1 equals about 61 percent and of scenario 2 about 30 percent of that for scenario 3. This means energy consumption in scenario 3 would be about 4,332 million MJ higher than in scenario 1 and about 7,695 million MJ higher than in scenario 2 (Table 40). Scenario 3 will spend water used cost in second rank because scenario 3 will require water less than scenario 1. Scenario 3 will spend highest fertiliser cost because scenario 3 will use highest fertiliser compare with other two scenario. According to Theng et al., (2014) the average of feriliser used in Cambodia found that farmers applied fertiliser at an average rate of about 242.23 kg/ha to vegetable crops. Based on this data, wet-season rice and vegetable crops in the potential area of 125,724 ha would use about 43,938 tonnes of fertiliser a year. Vegetable crops also need large quantities of pesticides. According to World Bank (2015), in 2013, farmers spent less than 4USD/ha on spraying wet-season rice and up to USD82/ha on vegetables. Based on these figures, pesticide costs for the potential area of 125,724 ha would amount to about USD10.81 million. Vegetable growing is labour intensive; among the three scenarios, production in scenario 3 needs the highest input of labour. Based on World Bank (2015) data for 2013, farmers used 27.75 days labour/ha for wet-season paddy and 169.85 days labour/ha for vegetables; and the average cost of hired labour was USD4.5/day. So, based on this data, annual labour costs in scenario 3 would amount to USD113.28 million. However, the higher costs of vegetable production are offset by the high vegetable crop gross margin per hectare, which is about 5.6 times higher than the wet-season rice gross margin and about 4.7 times higher than the dry-season rice gross margin.

9.3.3 Risks

Similarly to double rice cropping in scenario 1, rice and vegetable cropping in scenario 3 need substantial amounts of water. However, the level of risk is lower than in scenario 1 because less water is required. Total energy consumption for vegetables is relatively high at about 2.3 times that for rice. This means that energy sources for the potential area need to be considered. As in scenarios 1 and 2, there are risks associated with long-term use of chemical fertilisers and insecticides, but the degree of risk is higher because growing wet-season paddy and vegetables uses the highest inputs. As in scenarios 1 and 2, CH4 and N2O emissions will increase under wet-season paddy and vegetables. But the level of risk is higher than in the other two scenarios if fertiliser is applied. This is because GWP under vegetables is lower than under rice when fertilised (Yuan et al. 2016). GWP is the same as in scenario 1.

9.3.4 With agricultural extension – CPRs and improved vegetable production practices

As discussed in Section 9.2.4, community fish refuges (CFRs) can increase ricefish yield. Because data on model vegetable farmers is not available, this study uses MAFF (2016) data on the highest vegetable yields attained in 2015. Average vegetable yield in 2015 was 8.58 t/ha (8.24 t/ha for wet-season crops and 9.03 t/ha for dry-season crops). The higher dry-season vegetable yield was chosen to estimate vegetable production in terms of protein, calories and lysine in scenario 3. This study assumes that farmers were able to achieve high vegetable yields as a result of training and special support. Projected vegetable production under scenario 3 in the potential area would increase: protein production would reach about 23,046 t/year, calorie production about 306 million kcals/year, and lysine production about 1,135 t/year. If farmers were to both adopt CFR for ricefield fish and attain high vegetable yields, projected annual food production in the potential area would improve, providing about 192,842 tonnes of protein, about 1,941 million kcals and about 15,939 tonnes of lysine (Table 44). Improved total annual food production under scenario 2 in the potential production area would provide about 170,976 tonnes of protein, about 1,652 million kcals and about 14,908 tonnes of lysine (Table 43).

Table 44: Projection of food production with CFR adaptation and highest vegetable yield in scenario 3

Scenario 3	Protein (t)	Calories ('000 kcals)	Lysine (t)
Wet-season rice	10,920.03	519,793.22	333.42
Ricefield fish + CFR	158,361.95	1,111,903.06	14,429.47
OAA	513.56	3,306.03	40.51
Vegetables + highest yield*	23,046.34	306,527.68	1,135.29
Total	192,841.87	1,941,529.98	15,938.69

Note: * based on data from MAFF 2016.

9.3.5 Summary

Integrated wet-season rice/fish/OAA/vegetables provides the highest current food supply and food product projection of protein and lysine, and the second highest current food supply and food product projection of calories. 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, insecticide and labour costs, and the second highest water cost.

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

Fertiliser and insecticide 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 fertilisation and pesticide application. Similarly, increased CH4 and N2O 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.

9.4 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 vegetable yield. Projected annual food production in terms 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 (Table 45).

Table 45: Comparison of food production with technology and best practice adoption between scenarios

	Protein (t)	Calories ('000 kcals)	Lysi ne (t)
Scenario 1	90,521.28	4,308,812.93	2,763.92
Scenario 2	170,976.22	1,652,078.90	14,908.33
Scenario 3	192,841.87	1,941,529.98	15,938.69
Scenario 1/Scenario 3 (%)	46.94%	221.93%	17.34%
Scenario 1/Scenario 2 (%)	52.94%	260.81%	18.54%
Scenario 2/Scenario 3 (%)	88.66%	85.09%	93.54%
Scenario 1 - Scenario 2	-80,454.94	2,656,734.03	-12,144.41
Scenario 3 - Scenario 1	102,320.59	-2,367,282.94	13,174.77
Scenario 3 - Scenario 2	21,865.65	289,451.08	1,030.36

A few highlights stand out from comparison of the results with and without training and technology/best practices adoption (CFR, SRI, high vegetable yield):

- Projected protein production in scenario 3 is highest with and without training and technology adoption. But, with training and new technologies, scenario 1 drops from second to third ranking and scenario 2 rises from third to second place (Table 46).
- For projected food production in terms of calories, there is no change in ranking; scenario 1 is highest, followed by scenario 3 (Table 46).
- Projected lysine production in scenario 3 is highest with and without training and technology adoption. If farmers receive training and adopt new technologies, scenario 1 drops from second to third ranking and scenario 2 rises from third to second place (Table 46).

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.

Table 46: Comparison of the three scenarios with and without training and technology adoption

Scenarios	Protein rank		Calorie rank		Lysine rank	
	No adaptation	Training and technologies adaptation	No adaptation	Training and technologies adaptation	No adaptation	Training and technologies 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

10. CONCLUSION

The benefits of scenario 1 include increased income from rice export, highest current food supply and highest food product projection of calories, and second highest current food supply and food supply projection of protein and second highest food supply projection of lysine. However, this scenario has the highest water costs and the second highest costs for energy, fertiliser, insecticide and labour. The significant amounts of water needed make production in scenario 1 the most risky, not to mention the negative effects of hydropower dams and climate change on water quantity and quality. Irrigation system or water supply costs would need to be considered. Although ranked second for energy consumption, support would be needed to manage the implications of high-energy agriculture. Double rice crops require a higher rate of fertilisation than single rice crops, though lower than that for wet-season rice and vegetables. Long-term use of inorganic fertilisers can alter soil chemistry and biology, and harm the soil ecosystem. Increased inorganic fertiliser use heightens these risks but less so than in scenario 3. Similarly, scenario 1 uses pesticide in second ranked in the potential area. Pesticide hazards include direct impacts on human health, food safety, environmental health, surface, soil fertility, air, soil and water quality, and non-target vegetation and organisms. Methane and nitrous oxide emissions will increase under double paddy. With fertilisation, the global warming potential of scenario 1 will be higher than scenario 3, but without fertilisation it will be the same. If farmers adopt system of rice intensification (SRI) methods, scenario 1 could produce more food (protein, calories and lysine) using 50 percent less water, while simultaneously reducing energy and inorganic fertiliser inputs and improving soil quality and water retention.

Scenario 2 stands to provide the second highest current food supply of lysine but the lowest current food supply and food production projection of protein and calories. This scenario has the lowest costs. The risks to production are the same as for scenario 1 but the level of risk is lower than for scenario 1 because it uses the lowest inputs of water, energy, fertiliser and insecticide. If farmers adopt community fish refuges, projected food production (protein, calories and lysine) in the potential area would increase.

Scenario 3 will provide the highest current food supply and food product projection of protein and lysine, and the second highest current food supply and food product projection of calories. Importantly, the four sources of protein can help reduce the incidence of stunting and underweight in Cambodia. The gross margin of vegetables is higher than that of wet-season and dry-season rice, and vegetable production would help meet domestic demand for fresh produce. However, energy, fertiliser, insecticide and labour costs are the highest, and water costs the second highest, among the three scenarios. Water use is high and poses the main risk to production, as in scenario 1, though the level of risk is lower. Energy consumption is the highest among the scenarios. This would require attention to energy supply in the potential area. The risks from fertiliser and insecticide use are the same as for scenarios 1 and 2, but the level of risk is higher because higher rates of fertiliser and insecticide are applied to wet-season paddy and vegetables. The risk associated with increases in methane and nitrous oxide emissions is the same as for scenarios 1 and 2; the level of risk is higher with inorganic fertiliser application, but the same without them. If farmers were to adopt community fish refuges (CFRs) and attain high vegetable yields, scenario 3 would produce more food in terms of protein, calories and lysine.

Comparison between the three scenarios with and without training and best practice/technology adoption (CFRs, SRI, high vegetable yield) shows that: (1) projected protein production would be highest in scenario 3 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. Further, the study shows that SRI adoption in scenario 1 helps reduce water use by 50 percent, and CFR adoption in scenarios 2 and 3 saves water and energy.

Overall, scenario 3 has the highest potential for improving food production in terms of protein, calories and lysine in the potential area.

REFERENCES

Abrams, Julian Hilton. 2015. Climate Resilient Irrigation Training: Promoting Climate Resilient Water Management and Agriculture Practice in Rural Cambodia.

ADB. 2008. Issues and Options in Agriculture and Natural Resources Sector in Cambodia.

———. 2012. The rice situation in Cambodia. Technical assistance consultant's report.

———. 2015. Key Indicators for Asia and the Pacific 2015.

Ahmed M., Hap Navy, Ly Vuthy, Tiongco M. 1998. Socioeconomic assessment of freshwater capture fisheries in Cambodia: report on a household survey. Phnom Penh, Cambodia: Mekong River Commission.

Aktar, Wasim, Dwaipayan Sengupta, and Ashim Chowdhury. 2009. "Impact of pesticides use in agriculture: their benefits and hazards." Interdisciplinary toxicology no. 2 (1):1-12.

Arias, Mauricio E, Thomas A Cochrane, Thanapon Piman, Matti Kummu, Brian S Caruso, and Timothy J Killeen. 2012. "Quantifying changes in flooding and habitats in the Tonle Sap Lake (Cambodia) caused by water infrastructure development and climate change in the Mekong Basin." Journal of environmental management no. 112:53-66.

Bansok, Ros, Chhim Chhun, and Nang Phirun. 2011. Agricultural Development and Climate Change: The Case of Cambodia. CDRI.

Bell, RW, V Seng, Noel Schoknecht, Wendy Vance, and S Hin. 2005. "Assessing land suitability for crop diversification in Cambodia."

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: 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."

Bünemann, Else K, and Annie McNeill. 2004. "Impact of fertilisers on soil biota." Soil Biology in Agriculture:64.

CAERT. 2011. The Importance of Proteins, Minerals, and Vitamins

Cagauan, AG, RD Branckaert, and C Van Hove. 2000. "Integrating fish and azolla into rice-duck farming in Asia." Naga, The ICLARM Quarterly no. 23 (1):4-10.

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 no. 46 (4):655-666.

CARD. 2014. National Strategy for Food Security and Nutrition (NSFSN 2014-2018). Phnom Penh.

CDHS. 2014. Cambodia Demographic and Health Survey. Phnom Penh: National Institute of Statistics.

CDRI. 2011. Irrigation Water Productivity in Cambodian Rice Systems.

CEDAC. 2009. Inventory of irrigation schemes and farmer water user committees in Cambodia. Case study: Situation within 13 out of 24 provinces. CEDAC Farmer and Water Program.

Chea, Chou, Phirun Nang, Isabelle Whitehead, Phillip Hirsch, and Anna Thompson. 2011. Decentralised governance of irrigation water in Cambodia: Matching principles to local realities: CDRI.

Chou, Chea. 2010. The local governance of common pool resources: The case of irrigation water in Cambodia: Cambodia Development Resource Institute Phnom Penh.

CNMC. 2000. "Environment, Hydraulic and Morphology in Chaktomuk, Phase 1.

Cambodian National Mekong Committee. The Ministry of Public and Transport, Phnom Penh.
Dang, DT, ME Arias, PDT Van, TT Vries, and TA Cochrane. 2015. "Analysis of water level changes in the Mekong Floodplain impacted by flood prevention systems and upstream dams."
De Silva, Sanjiv, Robyn Johnston, and Senaratna Sellamuttu. 2014. Agriculture, irrigation and poverty reduction in Cambodia: Policy narratives and ground realities compared.
Douven, WJAM, Marc Goichot, and Henk Verheij. 2009. Roads and Floods: Best Practice Guidelines for the Integrated Planning and Design of Economically Sound and Environmentally Friendly Roads in the Mekong Floodplains of Cambodia and Viet Nam: Synthesis Report. Delft Cluster.
Dugan, Patrick. 2008. "Mainstream dams as barriers to fish migration: international learning and implications for the Mekong."
FAO. 1953. Food composition tables for international use.
———. 1981. Food and Agriculture Organization of the united nations organisation des nations unies pour l'alimentation et l'agriculture organizacion de las naciones unidas para la agricultura y la alimentacion.
———. 2001. Food Balance Sheets.
———. 2008. http://www.fao.org/docrep/013/al936e/al936e00.pdf.
———. 2014. Contry Fact Sheet on Food and Agriculture Policy Trends. Food and Agriculture Policy Decision Analysis.
———. 2016a. Food data at http://faostat3.fao.org/home/E.
———. 2016b. Gross Value of Paddy Rice Production Data at http://faostat3.fao.org/home/E.
———. Two Champion Farmers from Cambodia (http://www.fao.org/3/a-be862e.pdf (accessed 5 March 2017) 2017.
FiA. 2011. The Strategic Planning Framework for Fisheries: 2010 – 2019.
Finlayson, C.M., and A.G. Spiers. 1999. "Global review of wetland resources and priorities for wetland inventory. Supervising Scientist Report 144/Wetlands International Publication 53, Supervising Scientist, Canberra, Australia."
Fisheries, Dependent on Inland. 2003. understanding livelihoods dependent on inland fisheries in bangladesh and southeast asia.
GDA. 2014. Annual report for The General Directorate of Agriculture 2014-2015.
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).
GTZ. 2004. " Evaluation of the System of Rice Intensification (SRI) in Cambodia. Report to GTZ, Phnom Penh. ."
Guttman, H. . 1999. Rice-field Fisheries — A Resource for Cambodia. AIT Aqua Outreach Unpublished Paper.
Hang, Saing Chan, HEM Socheth, and OUCH Chandarany. 2011. Foreign investment in agriculture in Cambodia: Cambodia Development Resource Institute.
Hortle, Kent G. 2007. Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin. In MRC technical paper.
Hortle, KG, 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.

iDE. 2005. Strategic Study of Groundwater Resources in Prey Veng and Svay Rieng (Phase 1) Final Report. Phnom Penh: iDE.

IFReDI. 2012. Food and Nutrition Security Vulnerability to Mainstream Hydropower Dam Development in Cambodia: Baseline Assessment of Diet and Nutrition in Cambodia 2011.

———. 2013. “Food and Nutrition Security Vulnerability to Mainstream Hydropower Dam Development in Cambodia.”

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: World Congress on Conservation Agriculture, 26 - 29 September, Brisbane, Australia.

ITC. 2014. Trade statistics for international business development at http://www.trademap.org/.

Jirawut, WA. 2012. “Increasing rice production: solution to the global food crisis.” URL: http:// www. nodai. ac. jp/cip/iss/english/9th_iss/fullpaper/1-2-2ku-jirawut. pdf.

Joffre, Olivier, Mam Kosal, Yumiko Kura, Pich Sereywath, and Nao Thuok. 2012. “Community fish refuges in Cambodia–Lessons learned.” Phnom Penh, Cambodia, The WorldFish Center.

Johnston, R, M Roberts, T Try, and S de Silva. 2015. Groundwater for irrigation in Cambodia.

Kingston, DG, JR Thompson, and Geoff Kite. 2011. “Uncertainty in climate change projections of discharge for the Mekong River Basin.” Hydrology and Earth System Sciences no. 15 (5):1459-1471.

Kummu, Matti, and Juha Sarkkula. 2008. “Impact of the Mekong River flow alteration on the Tonle Sap flood pulse.” AMBIO: A Journal of the Human Environment no. 37 (3):185-192.

MAFF. 2010b. Annual Report for Agriculture Forestry and Fishery 2009-2010

———. 2011. Action Plan for Implementing Policy Paper on The Promotion of Paddy Production and Rice Export Rice.

———. 2012. Report of the Annual Conference 2011-2012. MAFF, Phnom Penh, Cambodia.

———. 2015a. Agricultural Sector Strategic Development Plan 2014-2018. Vol. 1: Univ of California Press.

———. 2015b. Annual Report for Agriculture Forestry and Fishery 2014-2015.

———. 2015c. Agricultural Extension Policy in Cambodia 2015.

———. 2016. Annual Report for Agriculture Forestry and Fishery 2015-2016.

MAFF, and MOWRAM. 2010. Strategy for Agriculture and Water 2010-13.

McKenney, Bruce, and Prom Tola. 2002. Natural resources and rural livelihoods in Cambodia: A baseline assessment. Vol. 23: Cambodia Development Resource Institute.

MoC. 2014. Products Export Data.

Molle, Francois, Tira Foran, and Philippe Floch. 2009. “Introduction: changing waterscapes in the Mekong region: historical background and context.” In.

MOWRAM. 2003. “Irrigated Agriculture. Phnom Penh, Cambodia.”.

———. 2009. Situation of Irrigation Schemes in Cambodia. Phnom Penh, Cambodia.

MRC. 1998. “Conceptual framework report: Water utilization programme. Prepared by SMEC and Funded by Global Environmental Facility.”

———. 2005. Overview of the Hydrology of the Mekong Basin. Mekong River Commission, Vientiane, 73 p.

———. 2010. Land cover for agriculture in Cambodia in 2010

MRCS/WUP-FIN. 2007. Final Report—Part 2: Research findings and recommendations. WUP-FIN Phase 2—Hydrological, Environmental and Socio-Economic Modelling Tools for the Lower Mekong Basin Impact Assessment, Mekong River Commission and Finnish Environment Institute Consultancy Consortium, Vientiane, Lao PDR.

Mulia, Nurhasan , K. Maehre Hanne, Kjellevold Malde Marian, K. Stormo Svein, Halwart Matthias, James David, and O. Elvevoll Edel. 2010. "Nutritional composition of aquatic species in Laotian rice field ecosystems."

Nesbitt, Harry J. 1997. Rice production in Cambodia: Int. Rice Res. Inst.

NIS. 2014. National Accounts of Cambodia 1993-2014.

———. 2015a. Census of Agriculture of the Kingdom of Cambodia 2013.

———. 2015b. Cambodia Socio-Economic Survey 2014.

ODC. 2015. Rice map of Cambodia at www.opendevelopmentcambodia.net/kh/maps/.

———. 2016a. Laws and Regulations of Agriculture and Fishing at www.opendevelopment cambodia.net/laws_and_regulations/agriculture-and-fishing/?post_type=law.

———. 2016b. Soil Fertility of Cambodia at www.opendevelopmentcambodia.net/kh/maps/.

Ogbodo, EN. 2013. "Impact of the use of inorganic fertilizers to the soils of the Ebonyi State Agro-Ecology, South-Eastern Nigeria." Journal of Environment and Earth Science no. 3 (7).

Olivier, Ecker, and Diao Xinshen. 2011. Food Security and Nutrition in Cambodia: Pattern and Pathways. Phnom Penh: Cambodia Development Resource Institute.

Perera, LR. 2006. Factors affecting the formation of FWUCs in institution building for PIMD in Cambodia: Two case studies. Vol. 113: IWMI.

Phaloeun, C, J Basnayake, C Kim Ngoy, S Fukai, and M Sarom. 2004. "The effect of water availability on rice-based double cropping in rainfed lowlands in Cambodia." Water in Agriculture no. 116.

Pittock, Jamie, David Dumaresq, and Stuart Orr. 2015. "The Mekong River: trading off hydropower, fish and food."

Rab, Mohammed A, Hap Navy, Seng Leang, Mahfuzuddin Ahmed, and Katherine Viner. 2006. "Marketing infrastructure, distribution channels and trade pattern of inland fisheries resources, Cambodia: an exploratory study." WorldFish Center, Buta Maung Penang, Malaysia. 42p.

RGC. 2010a. The Promotion of Paddy Production and Rice Export.

———. 2010b. Strategy for agriculture and water – Harmonized program design document – Final. Technical Working Group on Agriculture and Water. 217pp.

———. 2011. The Strategic Planning Framework for fisheries 2010-2019.

———. 2013. Rectangular Strategy III.

———. 2014. National Strategy for Food Security and Nutrition 2014-2018

———. 2015. National Strategic Development Plan 2014-2018.

Sobrado, Carlos, Samsen Neak, Sodeth Ly, Enrique Aldaz-Carroll, Elisa Gamberoni, Francisco Arias-Vazquez, Tsuyoshi Fukao, Simeth Beng, Timothy Johnston, and Miguel San Joaquin. 2014. "Where have all the poor gone?: Cambodia poverty assessment 2013." World Bank Country Study, Washington, DC: World Bank.

Tech, Chey. 2004. " Ecological System of Rice Intensification (SRI) Impact Assessment. CEDAC Field Document. ."

Theng, Vuthy, Pirom Khiev, and Dary Phon. 2014. Development of the Fertiliser Industry in Cambodia: Structure of the Market, Challenges in the Demand and Supply Sides, and the Way Forward.

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

Thun, V, V Suon, D Khiev, and B Ros. 2009. "Water use conflicts and their impact on rice yield in Takeo province, Cambodia." Special and Technical Paper No tp201003t1. Economy and Environment Program for Southesat Asia. South Bridge Court, Singapore:1-33.

Thuon, T., L. R. Perera, M. Bhattarai, and S. Vong. 2007. Socio-economic and environmental concerns in Stung Chinit irrigation project in Cambodia: Issues and reflections from rapid assessment. Draft Discussion Paper. Mekong Wetland Biodiversity Conservation and Sustainable Use Program (MWBP). 51 pp.

Troeung, R, S Aun, S Lieng, L Deap, 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. Paper read at MRC Conference Series.

UN. 2016. UN Comtrade Database at www.comtrade.un.org/data/ (accessed 26 February 2016).

UNDP. 2010. Cambodia Community Based Adaptation. Project Document Report: Phnom Penh.

———. 2011. Building Resilience: The Future for Rural Livelihoods in the Face of Climate Change. Cambodia

Human Development Report: Phnom Penh.

———. 2013. Industry-Agriculture Linkages: Implications for rice policy.

Van Zalinge, Nicolaas, ST Nao, ST Touch, and L Deap. 2000. Where there is water, there is fish? Cambodian fisheries issues in a Mekong River basin perspective, in McKenney, B., & Tola, P. (2002). Natural Resources and Rural Livelihoods in Cambodia: A Baseline Assessment. Phnom Penh, Cambodia: CDRI.

Vuthy, Theng. 2013. A Policy Dialogue on Rice Futures: Rice-Based Farming Systems Research in the Mekong Region.

Vuthy, Theng, and Koy Ra. 2010. "Review of agricultural policy and policy research." Presentation made at the Cambodia Food Security and Agricultural Policy Stocktaking Roundtable, Phnom Penh, Cambodia.

Wokker, Christopher, Paulo Santos, and Ros Bansok. 2014. "Irrigation water productivity in Cambodian rice systems." Agricultural Economics no. 45 (4):421-430.

World Bank. 2015. Cambodian Agriculture in Transition: Opportunities and Risks: World Bank.

Yu, Bingxin, and Xinshen Diao. 2011. "Cambodia's agricultural strategy: Future development options for the rice sector." Cambodia Development Resource Institute (CDRI), Council for Agricultural and Rural Development (CARD), and IFPRI Special Report. Phnom Penh, Cambodia: CDRI no. 1284 (1283):1282.

Yu, Bingxin, and Shenggen Fan. 2011. "Rice production response in Cambodia." Agricultural Economics no. 42 (3):437-450.

Yuan, Ye, Xiaoqin Dai, Huimin Wang, Ming Xu, Xiaoli Fu, and Fengting Yang. 2016. "Effects of Land-Use Conversion from Double Rice Cropping to Vegetables on Methane and Nitrous Oxide Fluxes in Southern China." PloS one no. 11 (5):e0155926.

APPENDICES

Appendix 1: Soil fertility by province (million ha)

Province	Low	Medium	High
Banteay Meanchey	0.262	0.187	0.166
Battambang	0.156	0.008	1.020
Kompong Cham	0.055	0.330	0.558
Kompong Chhnang	0.285	0.051	0.194
Kompong Speu	0.516	0.121	0.059
Kompong Thom	0.445	0.278	0.521
Kampot	0.352	0.106	0.012
Kandal	0.032	0.277	0.046
Kep	0.015	0.000	0.000
Koh Kong	0.963	0.046	0.079
Kratie	0.600	0.151	0.445
Mondolkiri	0.825	0.072	0.460
Oddar Meanchey	0.514	0.077	0.071
Pailin	0.019	0.000	0.088
Phnom Penh	0.007	0.024	0.006
Preah Sihanouk	0.224	0.019	0.007
Preah Vihear	0.987	0.067	0.346
Prey Veng	0.000	0.469	0.005
Pursat	0.808	0.083	0.265
Ratanakkiri	0.606	0.053	0.503
Siem Reap	0.546	0.269	0.239
Stung Treng	0.768	0.217	0.204
Svay Rieng	0.000	0.279	0.000
Takeo	0.065	0.280	0.000
Total	**9.050**	**3.465**	**5.295**

Source: ODC 2016

Appendix 2: Land cover in 2010

Land cover type	Area (million ha)
Annual crop	1.427
Aquaculture	0.003
Aquaculture (shrimp) rotated with paddy rice	0.000
Bamboo forest	0.077
Bare soil	0.032
Broadleaved deciduous forest	4.037
Broadleaved evergreen forest	2.824
Coniferous forest	0.002
Flooded forest	0.372
Forest plantation	0.001
Grassland	0.335
Industrial plantation	0.278
Mangrove	0.001
Marshes/swamp area	0.067
Orchard	0.022
Paddy rice	3.546
Paddy rice rotated with annual crop	0.291
Shrubland	1.393
Urban area	0.404
Water body	0.278
Total	15.389

Source: MRC 2010

Appendix 3: Single, double and triple crop areas

Agriculture area	Area (million ha)	
	2000	2010
Irrigated - double crop	1.377	2.427
Irrigated - single crop	0.158	0.467
Irrigated - triple/continuous crop	0.316	0.036
Rainfed crop	3.382	4.649
Total	5.233	7.580

Sources: IRRA 2000, 2010

Appendix 4: Rice supply per hectare in protein, calories and lysine in Cambodia, 2005-2011

Year	Supply (t/ha)	Protein (t/ha)	Calories ('000 kcals/ha)	Lysine (t/ha)
2005	0.83	0.06	2.98	0.002
2006	0.82	0.06	2.91	0.002
2007	0.81	0.06	2.91	0.002
2008	0.81	0.06	2.90	0.002
2009	0.80	0.06	2.87	0.002
2010	0.79	0.06	2.83	0.002
2011	0.89	0.07	3.18	0.003
Average	0.82	0.06	2.94	0.0025

Appendix 5: Bovine meat supply per hectare in protein, calories and lysine in Cambodia, 1980-2011

Year	Supply (t/ha)	Protein (t/ha)	Calories ('000 kcals/ha)	Lysine (t/ha)
1980	0.02	0.004	0.06	0.0004
1981	0.03	0.005	0.07	0.0004
1982	0.03	0.006	0.08	0.0005
1983	0.04	0.007	0.09	0.0006
1984	0.04	0.007	0.11	0.0007
1985	0.04	0.008	0.11	0.0007
1986	0.05	0.009	0.13	0.0008
1987	0.05	0.009	0.14	0.0008
1988	0.06	0.010	0.14	0.0009
1989	0.06	0.010	0.14	0.0009
1990	0.06	0.011	0.15	0.0009
1991	0.06	0.010	0.15	0.0009
1992	0.06	0.011	0.16	0.0010
1993	0.07	0.012	0.17	0.0011
1994	0.06	0.011	0.16	0.0010
1995	0.07	0.012	0.17	0.0011
1996	0.07	0.012	0.18	0.0011
1997	0.07	0.013	0.18	0.0011
1998	0.07	0.012	0.17	0.0010
1999	0.07	0.012	0.17	0.0010
2000	0.07	0.013	0.19	0.0012
2001	0.06	0.011	0.16	0.0010
2002	0.05	0.010	0.14	0.0009
2003	0.05	0.009	0.13	0.0008
2004	0.05	0.008	0.12	0.0007
2005	0.04	0.008	0.11	0.0007
2006	0.05	0.008	0.12	0.0007
2007	0.05	0.008	0.12	0.0008
2008	0.05	0.009	0.12	0.0008
2009	0.05	0.009	0.13	0.0008
2010	0.05	0.009	0.12	0.0008
2011	0.05	0.009	0.12	0.0008
Average	0.05	0.01	0.14	0.0008

Appendix 6: Vegetable supply per hectare in protein, calories and lysine in Cambodia, 1996-2011

Year	Supply (t/ha)	Protein (t/ha)	Calories ('000 kcals/ha)	Lysine (t/ha)
1996	5.35	0.11	1.44	0.01
1997	4.38	0.09	1.18	0.00
1998	5.22	0.11	1.41	0.01
1999	5.20	0.11	1.40	0.01
2000	5.52	0.11	1.49	0.01
2001	4.72	0.10	1.27	0.00
2002	3.73	0.08	1.01	0.00
2003	3.26	0.07	0.88	0.00
2004	4.90	0.10	1.32	0.00
2005	4.23	0.09	1.14	0.00
2006	4.49	0.09	1.21	0.00
2007	4.75	0.10	1.28	0.00
2008	4.87	0.10	1.31	0.00
2010	6.62	0.13	1.79	0.01
2011	7.68	0.16	2.07	0.01
Average	4.99	0.10	1.35	0.005

Appendix 7: Dry-season rice yield in protein, calories and lysine in Cambodia, 1980-2015

Year	Yield (t/ha)	Protein (t/ha)	Calories ('000 kcals/ha)	Lysine (t/ha)
1980	0.75	0.06	2.69	0.002
1981	1.12	0.08	4.01	0.003
1982	1.27	0.10	4.55	0.003
1983	1.27	0.10	4.53	0.003
1984	1.37	0.10	4.88	0.003
1985	1.31	0.10	4.67	0.003
1986	1.52	0.11	5.42	0.003
1987	1.58	0.12	5.63	0.004
1988	1.28	0.10	4.57	0.003
1989	1.54	0.12	5.48	0.004
1990	1.60	0.12	5.70	0.004
1991	1.61	0.12	5.75	0.004
1992	1.60	0.12	5.71	0.004
1993	1.60	0.12	5.71	0.004
1994	1.92	0.14	6.85	0.004
1995	1.92	0.14	6.85	0.004
1996	1.95	0.15	6.94	0.004
1997	1.95	0.15	6.96	0.004
1998	1.87	0.14	6.69	0.004
1999	1.94	0.15	6.94	0.004
2000	1.94	0.15	6.94	0.004
2001	2.06	0.15	7.37	0.005
2002	2.04	0.15	7.27	0.005
2003	2.03	0.15	7.25	0.005
2004	2.26	0.17	8.09	0.005
2005	2.50	0.19	8.91	0.006

2006	2.51	0.19	8.98	0.006
2007	2.53	0.19	9.04	0.006
2008	2.58	0.19	9.21	0.006
2009	2.64	0.20	9.43	0.006
2010	2.69	0.20	9.60	0.006
2011	2.82	0.21	10.07	0.006
2012	2.78	0.21	9.94	0.006
2013	2.80	0.21	10.01	0.006
2014	2.84	0.21	10.15	0.007
2015	2.83	0.21	10.10	0.006
Average	1.97	0.15	7.03	0.005

Appendix 8: Wet-season rice yield in protein, calories and lysine, 1980-2015

Year	Yield (t/ha)	Protein (t/ha)	Calories ('000 kcals/ha)	Lysine (t/ha)
1980	0.76	0.06	2.73	0.002
1981	0.67	0.05	2.41	0.002
1982	0.73	0.05	2.60	0.002
1983	0.78	0.06	2.78	0.002
1984	0.76	0.06	2.70	0.002
1985	0.76	0.06	2.70	0.002
1986	0.83	0.06	2.95	0.002
1987	0.77	0.06	2.76	0.002
1988	0.85	0.06	3.02	0.002
1989	0.87	0.07	3.10	0.002
1990	0.80	0.06	2.86	0.002
1991	0.83	0.06	2.95	0.002
1992	0.77	0.06	2.77	0.002
1993	0.77	0.06	2.74	0.002
1994	0.83	0.06	2.97	0.002
1995	1.05	0.08	3.75	0.002
1996	1.07	0.08	3.82	0.002
1997	1.02	0.08	3.62	0.002
1998	1.05	0.08	3.76	0.002
1999	1.15	0.09	4.11	0.003
2000	1.16	0.09	4.12	0.003
2001	1.27	0.10	4.54	0.003
2002	1.09	0.08	3.90	0.002
2003	1.25	0.09	4.46	0.003
2004	1.10	0.08	3.94	0.003
2005	1.45	0.11	5.17	0.003
2006	1.45	0.11	5.19	0.003
2007	1.54	0.12	5.51	0.004
2008	1.63	0.12	5.80	0.004
2009	1.68	0.13	5.99	0.004

2010	1.77	0.13	6.31	0.004
2011	1.87	0.14	6.67	0.004
2012	1.84	0.14	6.56	0.004
2013	1.87	0.14	6.68	0.004
2014	1.80	0.14	6.43	0.004
2015	1.81	0.14	6.46	0.004
Average	1.16	0.09	4.13	0.003

Appendix 9: Bovine meat yield in protein, calories, and lysine in Cambodia, 1980-2011

Year	Yield (t/ha)	Protein (t/ha)	Calories ('000 kals/ha)	Lysine (t/ha)
1980	0.023	0.004	0.060	0.0004
1981	0.027	0.005	0.070	0.0004
1982	0.033	0.006	0.084	0.001
1983	0.037	0.007	0.095	0.001
1984	0.042	0.007	0.108	0.001
1985	0.045	0.008	0.115	0.001
1986	0.049	0.009	0.125	0.001
1987	0.053	0.009	0.136	0.001
1988	0.055	0.010	0.142	0.001
1989	0.056	0.010	0.145	0.001
1990	0.060	0.011	0.153	0.001
1991	0.059	0.010	0.150	0.001
1992	0.064	0.011	0.164	0.001
1993	0.067	0.012	0.172	0.001
1994	0.064	0.011	0.163	0.001
1995	0.068	0.012	0.173	0.001
1996	0.069	0.012	0.177	0.001
1997	0.071	0.013	0.181	0.001
1998	0.066	0.012	0.169	0.001
1999	0.067	0.012	0.171	0.001
2000	0.074	0.013	0.189	0.001
2001	0.064	0.011	0.163	0.001
2002	0.054	0.010	0.138	0.001
2003	0.050	0.009	0.129	0.001
2004	0.046	0.008	0.119	0.001
2005	0.045	0.008	0.115	0.001
2006	0.047	0.008	0.120	0.001
2007	0.048	0.008	0.122	0.001
2008	0.049	0.009	0.124	0.001
2009	0.050	0.009	0.128	0.001
2010	0.048	0.009	0.124	0.001
2011	0.049	0.009	0.124	0.001
Average	0.053	0.009	0.136	0.001

Appendix 10: Vegetable yield in protein, calories and lysine in Cambodia, 1996-2015

Year	Yield (t/ha)	Protein (t/ha)	Calories ('000 kcals/ha)	Lysine (t/ha)
1996	5.96	0.12	1.61	0.01
1997	5.05	0.10	1.36	0.01
1998	5.88	0.12	1.59	0.01
1999	5.82	0.12	1.57	0.01
2000	6.10	0.12	1.65	0.01
2001	5.34	0.11	1.44	0.01
2002	4.36	0.09	1.18	0.00
2003	3.87	0.08	1.04	0.00
2004	5.54	0.11	1.50	0.01
2005	4.82	0.10	1.30	0.00
2006	5.07	0.10	1.37	0.01
2007	5.34	0.11	1.44	0.01
2008	5.44	0.11	1.47	0.01
2010	7.14	0.15	1.93	0.01
2011	8.29	0.17	2.24	0.01
2012	7.60	0.15	2.05	0.01
2013	8.71	0.18	2.35	0.01
2014	8.09	0.16	2.18	0.01
2015	8.58	0.17	2.32	0.01
Average	6.16	0.12	1.66	0.01

Appendix 11: Ricefield fish yield (kg/ha/year)

Sources	Ricefield fish yield (kg/ha/year)
Gregory, Guttman and Kekputhearith 1996	102.5
Nesbitt 1997	200-400
Guttman 1999	50-100
Troeung et al. 2003	55
Hortle, Troeung and Lieng 2008	90.44
Thouk 2009	50-100

Appendix 12: OAA yield (kg/ha/year)

Source	OAA supply (kg/ha/year)
Hortle et al. 2008	28.56
Gregory et al. 1996	22.50

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