Working Paper on Population Growth and Natural Resources Pressures in Pursat Catchment

Fostering Evidence-based IWRM in Stung Pursat Catchment (Tonle Sap Great Lake)

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Prepared for:

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WORKING PAPER ON POPULATION GROWTH AND NATURAL RESOURCE PRESSURES IN PURSAT CATCHMENT

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1.0 INTRODUCTION

The Project *Fostering evidence-based IWRM in the Stung Pursat Catchment (Tonle Sap Great Lake), Cambodia* (also known as *MK16*) was collaboratively implemented by the Ministry of Water Resources and Meteorology (MOWRAM), Tonle Sap Authority (TSA), Supreme National Economic Council (SNEC), Hatfield Consultants Partnership (HCP), and the Culture and Environment Preservation Association (CEPA) between December 2012 and December 2013. MK 16 is an initiative of the Challenge Program for Water and Food (CPWF), supported by funding from the Australian Aid program.

This project examined the linkages between population and demand for food and water. Cambodia, in general, and Pursat Province in particular, have a complex and interesting mosaic of demographic attributes and development issues. The Tonle Sap basin and Pursat catchment possess the country's largest potential water resources. These resources have the ability to support on-going economic development, including irrigation and agricultural production, fisheries and aquaculture, energy and forest products, navigation and other modes of transport, domestic and industrial water use and tourism (Pech and Sunada 2008).

MK16 is implemented in a single sub-catchment of Tonle Sap basin in western Cambodia, the Stung Pursat. The project sought to address and/or improve three inter-related aspects of water management: (a) cross-sectoral collaboration; (b) use of data and scientific analyses to inform water management in Cambodia; and, (c) institutional mechanisms for inter-sectoral management, and interpretation and use of existing or new scientific data.

1.1 PURPOSE AND OBJECTIVES

This working paper examines population growth in Pursat and its potential impact on food demand and land and water resources in a systematic and integrated manner. The main purpose of the paper is to kick-start a policy debate on population dynamics and food and water security in Pursat. The paper provides background information, observations and empirical analysis of resource demand (real or perceived) associated with population growth and policy decisions related to food and water security.

We present a constructive analysis to obtain a clear overview of demographic trends in Pursat, explore mechanisms for changes in population over time, as well as the complex relationships between demographic changes and natural resources in Pursat.

Population growth, food and water demands, and their impacts on water resources in the Mekong region and other parts of the world have been well documented (Borberg 2005; Molden *et al.* 2001; Rosegrant *et al.* 2002; Hoanh *et al.* 2003; Davis 2003). While these studies provide some background information about annual food and water demand at a broad scale, there is less information available at smaller temporal and spatial scales, such as during critical dry season months or around water storage infrastructure sites. Such information can be critical for understanding water resource requirements for meeting food demand and other basic human needs.

This paper also reviews population trends in Pursat through both quantitative and qualitative analysis. The report also explores the complex relationships between demographic changes and natural resources, including:

- relationship between population growth and demands for food and water;
- impacts of infrastructure and economic developments (hydropower, irrigation expansion, etc.) on water, land and other related natural resources, as well as on sustainable livelihoods of local communities.

2.0 DEMOGRAPHIC TRENDS IN CAMBODIA AND PURSAT

2.1 STUNG PURSAT SOCIAL AND DEMOGRAPHIC DYNAMISM

The MK 16 project focuses on the Stung Pursat, a tributary of the Tonle Sap Great Lake and one of its main catchments. The Stung Pursat catchment is 5,965 km^2 in area, and discharges an average of 2,818 million cubic meters (MCM) a year into the Great Lake along its western shore (JICA 2011). The population of Pursat Province is over 397,000 with more than 203,500 people (or over 51%) living in the Stung Pursat catchment, which occupies 77% of the province (NIS 2008). Dependence on the Stung Pursat's water and related resources is high, and exists beyond the hydrological boundary of Stung Pursat's catchment, due to various water diversions and trade with neighboring districts and provinces. A portion of the Stung Pursat flow is diverted through Damnak Ampil weirs to Svay Don Keo and Maung sub-basins. These diversions are particularly important and critical for the rural poor, who depend heavily on subsistence livelihoods (CNMC 2012).

Box 1 Provisional Population of Cambodia based on 2008 Census Figures (NIS 2008).

Number of Provinces		24
Number of Districts		185
Number of Communes		1,621
Number of Villages		14,073
Population of Cambodia	Both Sexes	13,388,910
	Males	6,495,512
	Females	6,893,398
Percentage of Urban Population		19.5
Annual Population Growth Rate (percent)		1.54
Density of Population (per km^2)		75
Sex Ratio (males per 100 females)		94.2
Average Size of Household (no. of members in a household)		4.7

Pursat is the fourth biggest province in Cambodia (in terms of land area). It is located in the western part of the country and borders Battambang Province to the north, the Tonle Sap Lake to the northeast, Kompong Chhnang to the east, Kompong Speu and Koh Kong to the south, and Thailand to the west. Pursat offers ideal access to both the Tonle Sap and the Cardamom Mountains (to the west). Like the rest of the country, Pursat is predominantly an agrarian province.

The majority of people in Pursat province and in adjacent catchments rely on the Pursat River and its associated floodplains for their livelihoods. Stung Pursat is listed as one of Cambodia's priority catchments due to its rich natural resources and wildlife sanctuaries (CNMC 2012). Competing water users/uses necessitate integrated and equitable management of the water resources.

Annual average population growth between 1998 and 2008 in Cambodia was 1.54%, while in Pursat it was estimated to be 0.77% (NIS 2008). The discrepancy between the two growth rates is due to a number of factors, such as a lack of surveying in 1998 and emigration from Pursat to other provinces (Battambang, Phnom Penh) and/or Thailand. The total number of households in Pursat in 2008 was 83,515, yielding an average household size of 4.7 persons (NIS 2008).

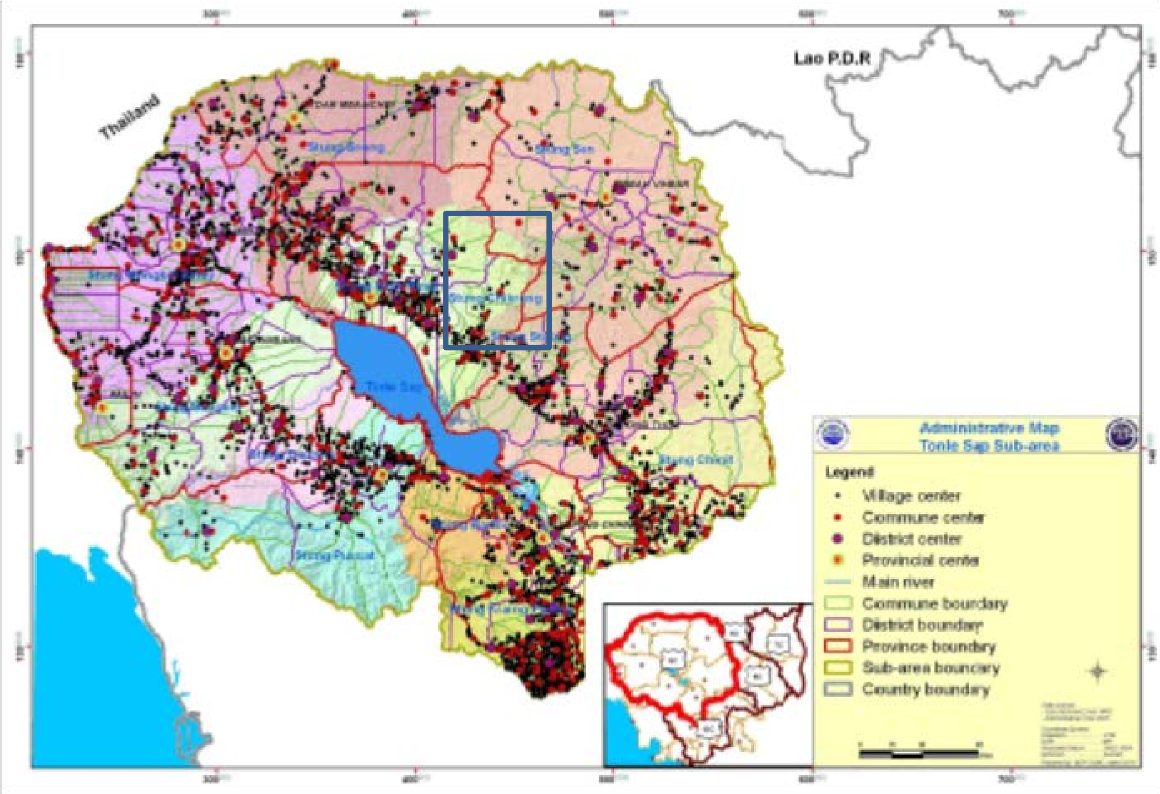
Table 1 Population Statistics in Pursat and Stung Pursat Catchment.

	Whole Province	Stung Pursat	Percent of total
Population (people) 2008	397,161	203,522	51%
# of Districts	6	6	100%
# of Communes	49	29	59%
# of villages	501	223	45%
Provincial city population	61,000	61,000	

Source: NIS 2008, CNMC 2012.

The people of Pursat Province live in six districts composed of 49 communes and 501 villages (CNMC 2012). The population density in the province, as shown in Figure 1 below, is 33 persons/km² compared to an average population density for Cambodia of 75 persons/km² (CPWFa and CPWFb 2013; WFP 2005).

Figure 1 Population Density in Pursat (CNMC 2012).



As shown in Figure 1, settlements are mainly along the Pursat River and within 50 km of both sides of the National Road 5 and the Pursat City, the provincial capital (also referred to as Pursat town). The city is located on the riverbanks of the Stung Pursat, directly between the Tonle Sap and the Cardamom Mountains.

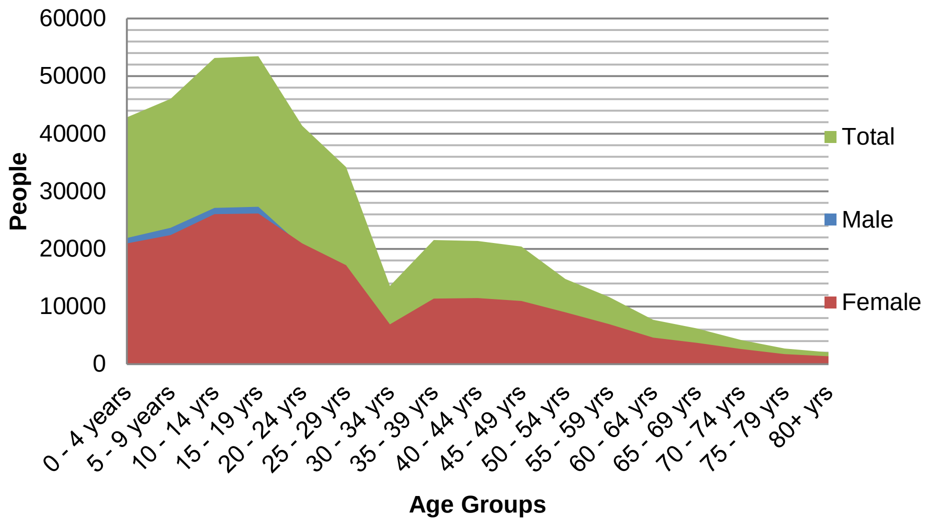
The province is characterized by high migration (mainly out of province), competition for natural resources, and variation in population density. These issues pose some uncertainty in terms of planning and development (CNMC 2012).

With a poverty ranking of 13 out of 24 provinces, Pursat has achieved some level of prosperity compared to other Cambodian provinces (USAID 2010). Pursat's economy is diverse and growing fast. Major economic activities include agriculture, fishing, livestock production, brick manufacturing, agriculture machinery, and handicrafts. Rice is the chief agricultural product, and other main crops include sugar palm, sweet potatoes, sesame, beans, mixed vegetables, corn and cassava. In total, there are about 1,000 private small and medium enterprises in Pursat, including manufacturing industries, ice factories, drinking water companies, a soft drink producer and horticulture (USAID 2010). Parts of the province have been allocated to a range of concessions, including agricultural concessions, economic land concessions and social concessions, by which land is granted to poor or landless farmers for farming or residential purposes (CNMC 2012). Land is also provided for mining through leases and possibly exploitation agreements (CNMC 2012). Pursat is attracting many private companies to invest in the agriculture sector; some new companies growing cassava and rubber in

Pursat have invested between $1 and $2 million each on 800-1000 ha parcels of land (USAID 2010).

Pursat has a young population (see Figure 2) and a falling Total Fertility Rate (TFR). As is the case for the entire country, Pursat is experiencing the beginning of a major transition in the population and human resource base, which creates both opportunities and challenges. With relatively few elderly or very young people, the economic ratio for dependency (workers to dependents) is low; in other words, the population is heavily weighted towards a population of productive workers (NIS 2008). However, with the opening up of the labour market, free movement of the labour force will encourage more Cambodian and Pursat workers to move across international borders in search of jobs. This could result in a labour shortage in the country, including Pursat. Moreover, with wages rising in neighbouring countries and the strengthening of their currencies, there are opportunities for Cambodia (including Pursat) for attracting relatively low-skill, labour-intensive industries (NIS 2008).

Figure 2 Population in Pursat by Age-Groups (NIS 2008 and US Census Bureau 2006).



The implications of population growth become clear when considering that more food items are required which in turn typically puts pressures on land, water, and other resources (Pech and Sunada 2008).

2.2 POPULATION GROWTH RATE PROJECTIONS

Projections of population growth in Pursat are varied due to poor reporting and lack of verified data. The population of Pursat is over 397,161 (NIS 2008) and is expected to increase rapidly in comparison to the national average rate of 1.54% and the provincial average of 0.77%, respectively (NIS 2008).

For the purposes of this working paper – of generating a debate about population changes and their impacts on natural resources – three population scenarios were created for Pursat based on estimates from the United Nations (UN) and Cambodia National Institute of Statistics (NIS):

- Scenario 1: The rate of natural increase (*r*) of Pursat is constant (exponential increase) at **0.77%**, which was estimated as the provincial average in 2008 (NIS 2008);
- Scenario 2: the adjusted UN Population natural increase rate (*r*) for Cambodia is reducing over time, as shown in Table 2 below, as a result of the observed decline in TFR, and annual out-migration rate of 1.50% until 2020 and at a rate of 1% thereafter; and
- Scenario 3: The rate of *r* is constant (exponential increase) **at 1.54%**, which was estimated as the national average growth rate (NIS, 2008).

Table 2 illustrates that the population growth rate for Scenario 2 is decreasing over time. For Scenario 2, the rate of natural increase for Pursat was estimated by considering birth rates per 1,000 people minus death rates per 1,000 people, and assuming that rate of out-migration is 1.5% until 2020 and 1% thereafter.

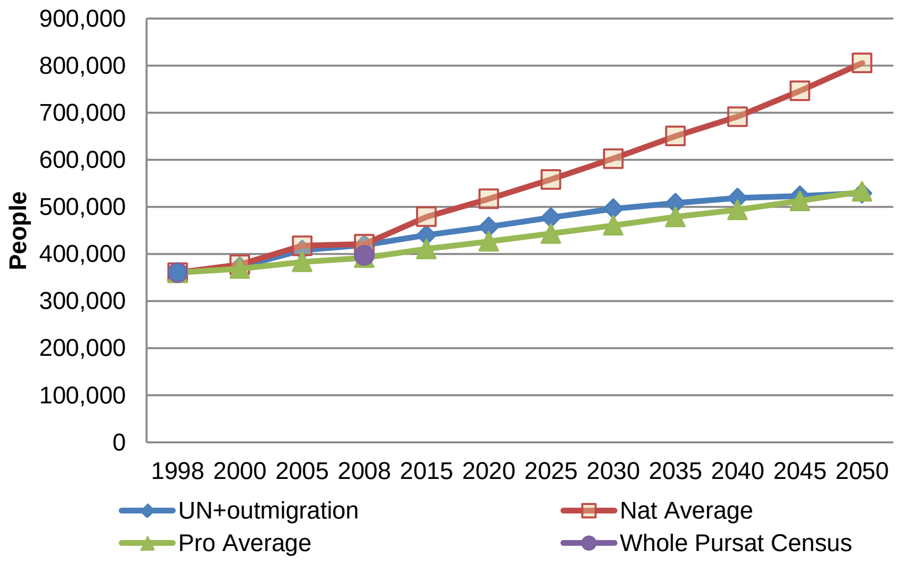
Table 2 Estimated Rate of Natural Population Increase for Pursat Province, Cambodia (in millions of people).

	1995	2005	2010	2020	2030	2040	2050
Birth/1,000	40.9	33.9	32.8	27.2	22.5	19.8	17
Death/1,000	11.7	10	10	8.7	7.8	7.6	7.7
Natural increase	2.92%	2.39%	2.28%	1.85%	1.47%	1.22%	1.22%
Out-migration rates	1.50%	1.50%	1.50%	1%	1%	1%	1%
Net growth rates	1.42%	0.89%	0.78%	0.85%	0.47%	0.22%	0.22%

2.3 DISCUSSION OF POPULATION GROWTH TRENDS IN PURSAT

Figure 3 shows the population growth trends based on the three population scenarios listed above. According to Scenario 1 (constant rate of increase of 0.77%), the population of Pursat Province grew from 360,445 people in 1998 (NIS census 1998) to over 392,000 people in 2008 (slightly lower than the 2008 census result of 397,161 people from NIS). Based on these projections, the population of Pursat will have increased by 47% by 2050 (total of 533,000 people). The population trend predicted by Scenario 2 (natural increase rate with an immigration rate of 1.50% until 2030 and 1% thereafter) is in general agreement with the data from the 1998 and 2008 census for Pursat. According to this scenario, the population of Pursat will have increased by 46% in 2050 to over 529,000.

Figure 3 Results of Population growth projections in Pursat (1998 – 2050).



According to Scenario 3, where the national population growth rate remains constant at 1.54%, the population of Pursat is expected to grow by 123% - more than double its 1998 values.

Scenarios 1 and 2 are more probable and favorable options for future population growth in Pursat. The rate of population increase peaked around 1990 and has since declined for the more populous Mekong countries, such as China and Thailand, due to the decline in TFRs (Pech and Sunada 2008).

Scenarios 1, 2 and 3 point to the complexity of estimating population growth trends, and planning for its impacts on natural resources. In order to fulfill the resource requirements of a growing population (perceived or real), ultimately some form of water and land-use change can be expected.

For decades, experts have debated about the relationship between population growth and economic development (Boberg 2005). Expert views range from:

- "Pessimistic" theory - insists that high fertility and rapid population growth inhibit development. This was dominant in 1960s;
- "Optimistic" theory - argues that rapid population growth and large population size promote economic growth by supplying abundant human and intellectual capital and increasing market size; and
- "Population neutralism" - maintains that population growth has some impact on economic performance only in combination with other intervening factors. This viewpoint has become the dominant view in current population policy (RAND Population Matters 2004).

Higher population numbers require more homes, factories, workplaces and manufacturers in order to house, employ, and feed a growing number of people (Bloom *et al.* 2003). However, population growth can also generate a "demographic dividend" (See **Box 2**), which can be understood as a window of economic opportunity associated with a drastic decline in the number of people not in the labour force. As a result, to derive a meaningful conclusion from analysis of population and economic growth relationships, one has to focus not only on the population size and growth and their age structure dynamics, but also on the policy and institution context (Boberg 2005).

Box 2 What is The Demographic “Dividend”?

The demographic dividend is delivered through a number of mechanisms. The most important are labour supply, savings, and human capital.

Labour Supply: The demographic transition affects labour supply in two ways. First, when a baby-boom generation is between 15 and 64, it is more likely to be working, thus lowering the ratio of dependents to non-dependents. During the peak working years of 20 to 54, this effect is especially strong. The number of people who would like to work (labour supply) therefore gets bigger and, provided the labour market can absorb the larger numbers of workers, per capita production increases. Second, women are more likely to enter the workforce as family size declines. In small families, children are more likely to be better educated. This increases their productivity in the labour market.

Savings: Working-age people tend to have a higher level of economic output and also a higher level of savings. Furthermore, people tend to save more between the ages of 40 and 65.

Human Capital: A longer life expectancy causes fundamental changes in the way that people live. People become more valuable assets.

All these mechanisms are heavily dependent on the policy environment. A growing number of adults will only be productive if there is sufficient flexibility in the labour market to allow its expansion and proper education. Finally, the demographic transition creates conditions where people will tend to invest in their own and their children’s health and education, offering great economic benefits, especially in the modern world’s increasingly sophisticated economies.

Source: Bloom *et al.* (2003)

Box 3 presents case studies from three different world regions undergoing a demographic transition. As illustrated by these case studies, the demographic dividend itself provides no guarantee of prosperity without an appropriate enabling policy environment. Without it, countries are too slow to adapt to their changing age structure, and miss an opportunity to secure high growth***. To reap opportunities presented by the demographic dividend, nations need effective policies in key areas, such as improvements in public health, effective population policy and family planning, proper policies in education, the economy, and governance*** (Bloom *et al*. 2003; Rand Population Matters 2004).

Box 3 Implications of demographic transitions - Case Studies of Population change and Economic.

East Asia: South Korea, Taiwan, and Hong Kong have been able to reap the demographic dividend produced by reduced fertility rates to produce robust economic growth between 1965 and 1990. As a result, the working-age population grew four times faster than dependent (youth and elderly) population. A better education system, and trade liberalization policies enabled national economies to absorb the "baby boom" generation into the workforce that fueled a spectacular economic boom - real per capita income grow an average 6% per year between 1965 and 1990.

Latin America: Latin American demographic changes have been favorable for growth since 1970. In spite of a fairly sharp demographic transition, Latin America has not capitalized on it because of a weak policy environment – such as weak governance and a lack of openness to trade.

Sub-Saharan Africa: Sub-Saharan Africa has experienced an extremely sluggish demographic transition. Traditionally high fertility and large family sizes have persisted in the face of improvement of infant and child mortality, and now the ravages of HIV/AIDS are depleting the working-age population. As a result, the proportion of the working age population remains low.

(Source: RAND Population Matters, 2004)

3.0 RELATIONSHIP BETWEEN POPULATION AND THE ENVIRONMENT

The relationship between population and the environment is complex (Hunter 2001). Population is a multidimensional concept that can relate to the size, distribution, density or composition of an area's inhabitants, as well as their level of income (Boberg 2005). In addition, the relationship is also influenced by other "mediating" factors, including technological (e.g., forms of energy production and consumption), political (e.g., policy environment), and cultural factors (e.g., ways of life and attitudes toward nature) (Boberg 2005).

As far as the relationship between population growth and natural resources in Pursat Province is concerned, two points can highlight the implications of population size and growth on natural resources. Fulfilling the resource requirements of a growing population ultimately requires some form of land-use change, be it to fill augmented food demand, or to develop infrastructure necessary to support increasing human numbers (Davis 2003). Secondly, the increase in agricultural production (expansion of agricultural areas and/or increase of land and water productivity) along with urbanization and industrialization can lead to an overall increase in demand for water and impacts on water and related resources (Pech and Sunada 2008).

Kristensen (2001) estimated that food demand from the Mekong River Basin would increase between 20% to 50% by 2030, alongside an increase in water demand. He stated that food production in the last 50 years has been roughly matched by a proportional increase in the use of water, fertilizers and other agro-chemical products, and with relatively slow increase in grain yields.

The following sections describe the potential impacts of population growth on: (i) food demand and production potential; (ii) land use and forest cover; (iii) trends in water demand and water balance; and, (iv) fishery resources.

3.1 FOOD DEMAND GROWTH PROJECTION IN PURSAT PROVINCE

3.2 SELECTING METHOD FOR PROJECTING FOOD DEMAND

Total food demand projections usually depend on three factors: (i) population size; (ii) increase in per capita consumption and lifestyle; and (iii) changes in the composition of diet (Pech and Sunada 2008). Data on the Pursat population size is available, as discussed above, and the changes in per capita consumption can be estimated from the food balance sheet developed by the Food and Agriculture Organization (FAO 2000).

Data on the composition of average daily diet for the years 1990, 1995 and 2000 in Cambodia shows that more than 65% of the daily calorie supply is provided by cereals (rice and wheat), both directly as cereal products and indirectly through animal products (FAO 2000). It is assumed in this study that this dietary composition will be maintained for the next 35 years, i.e. cereal products and rice will remain major staple food in Mekong River Basin (MRB) in the coming decades.

A study by the World Food Program confirmed that rice is the primary staple food-crop for Pursat province (WFP 2005)[1]. Most rural households in Pursat grow crops, most commonly rice, which is produced for personal consumption and for cash income at least for one season per year.

Some early studies calculated food demand based on an assumption for per capita demand of 300 kg/year of paddy or equivalent for all Mekong countries (e.g., Rosegrant et al. 2002). However, the analysis of the FAO Food Balance Sheet for the years 1990, 1995 and 2000 shows that this method was over-generalized, as food composition and availability vary from one country to another (FAO 2000). FAO (2000) provides information about the average per capita food supply, which can help in measuring long-term trends in national food demand and dietary composition. In this study, domestic food demand is defined as the sum of demand for food for personal consumption and for other uses of food, like seed use, livestock feed, food manufacturing, and farm and market waste (post-harvesting, transport and retail losses).

The per capita demand for cereal and rice varies from one Mekong country to another (Table 3) (FAO 2005). This working paper presents a more detailed assessment of the paddy rice needs, because rice cultivation dominates agriculture for a number of physical, biological, social and economic reasons. Food demand in Pursat is estimated by multiplying the per capita rice demand with the population (p) at a particular point in time.

[1] At http://www.foodsecurityatlas.org/khm/country/provincial-Profile/Pursat.

Table 3 **Per Capita Food Balance Sheet (kg) for Selected Mekong countries in 1990 and 2000 (FAO 2005).**

	Food		Feed		Seed		Waste		Manufacture		Paddy Equivalent	
	1990	**2000**	**1990**	**2000**	**1990**	**2000**	**1990**	**2000**	**1990**	**2000**	**1990**	**2000**
Cambodia - Rice	154.5	162.1	3.3	8.1	6.9	8.1	15.4	18.4	n.a	n.a.	290.4	301.1
Lao PDR - Rice	171.1	167.9	12.1	13.8	14.5	16.7	7.3	8.3	12.8	13	451.1	354.3
Thailand - Rice	109.5	105.4	10.5	14	7	7.2	12	15.9	3.5	3.8	230	236
Fruit	88.6						8.6				97.2	101.9
Vietnam - Rice	155	169.5	2.8	4.2	5.8	8.3	13.4	18.9	1.5	1.9	287	327

Fruit is included because it is second most important element in Thai diet and Cambodia's diet may follow that path in the next 10 years. (The estimated rice [milled equivalent] converted into paddy rice equivalent by applying FAO milling ratio 100/62. – 1870.1kg/capita in 1990, and 196.7 kg of milled/white rice in 2000)

3.3 FOOD DEMAND RESULTS

Table 4 below summarizes rice production by season in Pursat in 2004 (WFP 2005)[2]. Rice production mainly occurs in the wet season. While dry season rice production is limited, it produces higher yields. Dry season rice cultivation only happens in some communities, particularly those with access to groundwater or dry season surface water resources (due to flood recession or irrigation). The area of rice harvested in Pursat and Cambodia in 2004 was reduced substantially due to natural disasters, including flood, drought and/or insect-infestation.

Table 4 **Rice Crop Production by Season in Pursat in 2004 (WFP 2004).**

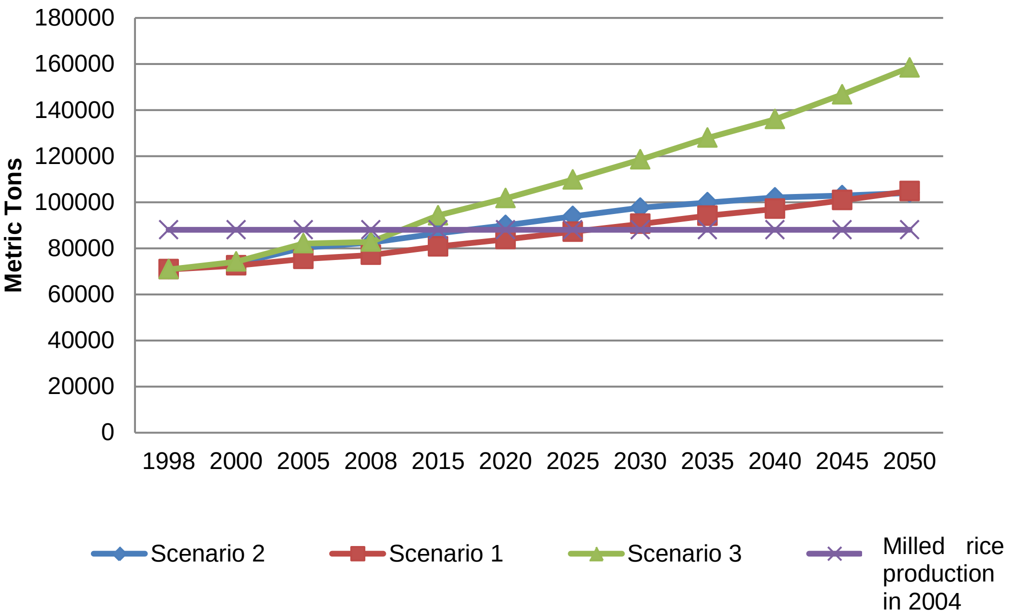
Rice Production Indicator	Pursat Wet Season	National Wet Season	Pursat Dry Season	National Dry Season
Area Cultivated- '000 ha.	90	2087	3	330
Area Harvested- '000 ha.	77	1851	3	3 318
Paddy Production '000 MT	147	2918	10	973
Yield-MT/ha.	1.9	1.6	3.3	3.1
Paddy % of total crop area cultivated	98%	81%	83%	84%
Mean Area Cultivated/ Rural HH- ha.	1.2	0.9	<0.1	0.1

In 2004, the minimum milled rice demand in Pursat was estimated to be around 80,000 metric tons compared to over 88,000 metric tons reportedly produced the same year (WFP 2004). Using this information, the MK 16 team made a simple assessment of future rice demand in Pursat. Assuming that food demand increases proportionally to population growth, projections for rice demand can be estimated using the same growth rates as population increase. Figure 4 presents the growth in rice demand based on the growth rates for Population Scenario 1

[2] World Food Program, 2004. Pursat Provincial Food Security Profile pages, accessed on line at http://www.foodsecurityatlas.org/khm/country/provincial-Profile/Pursat on July 8, 2013.

(constant natural increase rate of 0.77%), Population Scenario 2 (UN natural increase rate and out-migration), and Population Scenario 3 (constant growth rate 1.54%). Assuming the 2004 rice productivity level in Pursat (80,000 metric tons), Figure 4 below illustrates that Pursat can produce enough rice to feed its population (rice sufficiency) until 2020 or 2025. After this, the total white rice demand in Pursat will increase by 43% to 45%, up to around 100,000 tons by 2050 (Scenarios 1 and 2). If Pursat population grows at the national rate of 1.54% (Scenario 3), the rice demand will more than double the 2004 level and exceed the current production level well before 2015.

Figure 4 Projections of Rice Demand in Pursat Based on Population Scenarios.



The World Food Program (WFP 2004) reports that the incidence of malnutrition persists in the Mekong river basin due to imbalanced distribution of food. Other studies corroborate this finding, adding that malnutrition may occur from an insufficient cash income (or its equivalent in kind) to purchase rice, rather than an absolute lack of food (Pech and Sunada 2008).

At the provincial level, overall rice production in 2004 exceeded the minimum rice needs of the population; however, only 73% of the communes in Pursat produced enough rice to meet their minimum food needs, while 27% were not able to meet their minimum requirements (WFP 2004). Small-holder farmers (possessing land holdings between 0.1- < 1.0 ha) were only able to produce enough rice to meet 74% of their minimum rice consumption needs. Furthermore, landless households, who do not produce rice at all, must meet their demands by renting or sharing crop/rice land, bartering, fishing, selling non-timber products, or finding employment in the province or other places in the country or overseas (WFP 2004).

Food insecurity is also caused by the vulnerability of rural people to various natural and socio-economic shocks and stresses (economic crises, political turmoil, and floods, droughts, and other natural disasters), which can reduce their food supply or access. Substantial agro-ecological risks also exist, including damage or destruction to crop production, livestock morbidity and mortality, and changes to common property such as fisheries and forest resources; in 2004, 15% of wet season cultivated area was destroyed, mainly as a result of drought (WFP 2004).

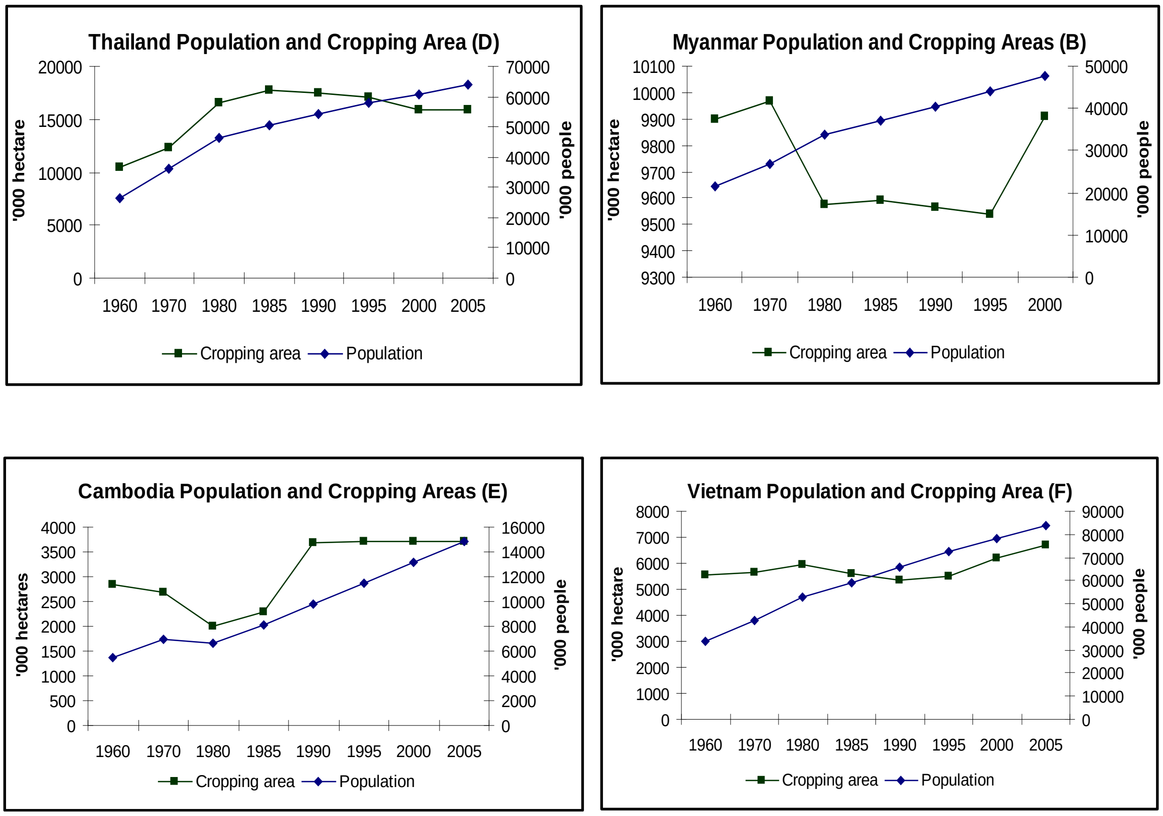
There are many opportunities and challenges facing food production in Pursat. Opportunities include the potential to increase irrigated land area, increase dry season rice production, diversify crops, increase non-agricultural income generation opportunities, and improve trade. On the other hand, challenges for food production stem from environmental constraints - like dry season water shortage, natural disasters, and soil availability and quality – and ineffective planning and resource governance

The change in age structure (greater proportion of people over 15 years) in Cambodia and Pursat accounts for 7% of the expected increase in food requirements (Davis 2003). Urbanization, too, can result in requirements for larger quantities of food and more dietary variety as incomes rise. Figure 4 is a simplified interpretation of the impact of demographic changes on food demand; it serves to urge the policy-makers and planners in Cambodia and Pursat to consider the importance of proper planning for, and close monitoring of, demographic change. The projections also illustrate the importance of planning on how to maximize agricultural production. These results were presented at the 2nd multi-stakeholder platform (MSP) session (September 10-11, 2013) – organized by the MK 16 project to convene key stakeholders in Stung Pursat – to generate meaningful discussion on this topic.

4.0 RELATIONSHIP BETWEEN POPULATION GROWTH AND AGRICULTURAL LAND EXPANSION IN MEKONG COUNTRIES

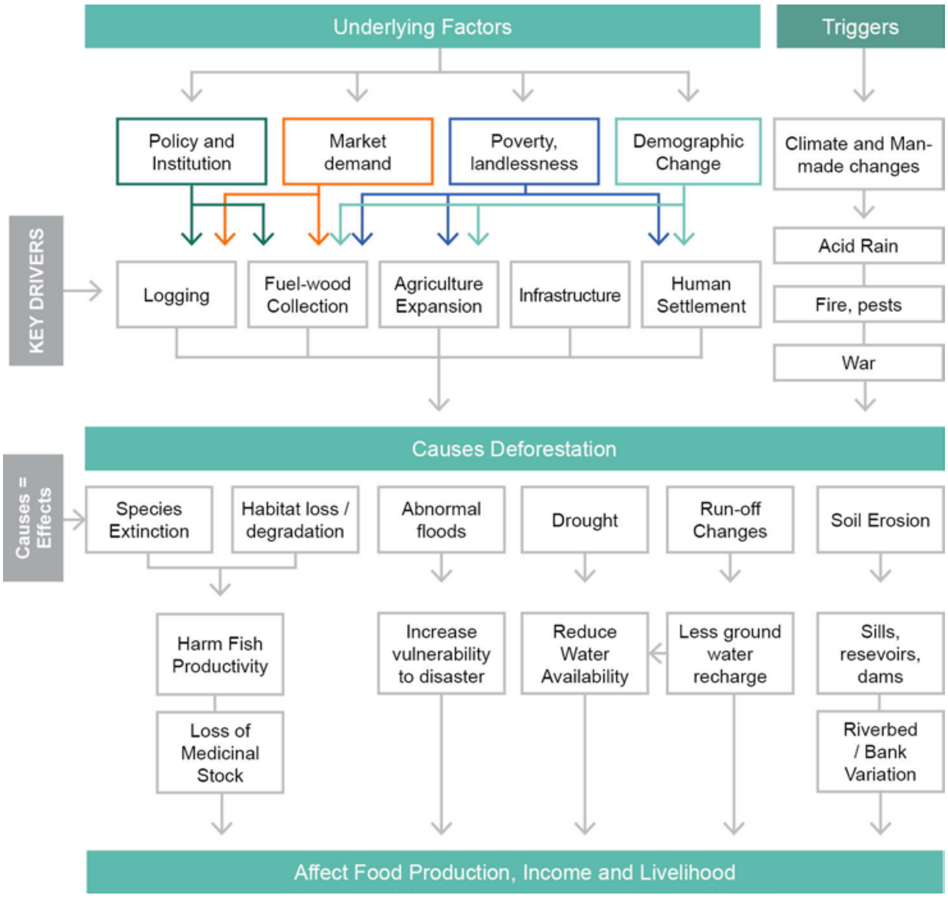
The relationship between demographic factors, mediating forces and deforestation is complex and not fully understood in Cambodia, especially in Pursat. As seen in Figure 5, the analysis of long-term population trends (United Nations 2005) and cropping-area changes in all Mekong countries during the past four decades (1960–2004) does not reveal a correlation between population growth and land-use change (ADB 2000; Pech and Sunada 2006). This suggests that agriculture expansion to meet a growing population is just one of the key causes of deforestation. Other factors include logging (illegal and legal), domestic and international market demand, infrastructure development, fuel-wood collection, and human settlement (ADB 2000; Pech and Sunada 2006). There are other factors that underlie deforestation as shown in Figure 6, including: institutional and policy changes (ban on logging combined with poor enforcement); lack of alternative energy supplies; poverty; small-area land-holding; demographic changes and migration; and threats posed to arable lands by land mines and unexploded ordnance (UXO).

Figure 5 Comparative analysis of population growth and agricultural land expansion in Mekong Region countries.



Data source: FAO, 2006 - Cropping land refers to land under temporary and permanent crops, temporary meadows, market and kitchen gardens, and temporarily fallow land.

Figure 6 Conceptual cause and effects of Deforestation (Pech and Sunada 2006).



4.1 FOOD DEMAND GROWTH AND IMPACTS ON LAND USE

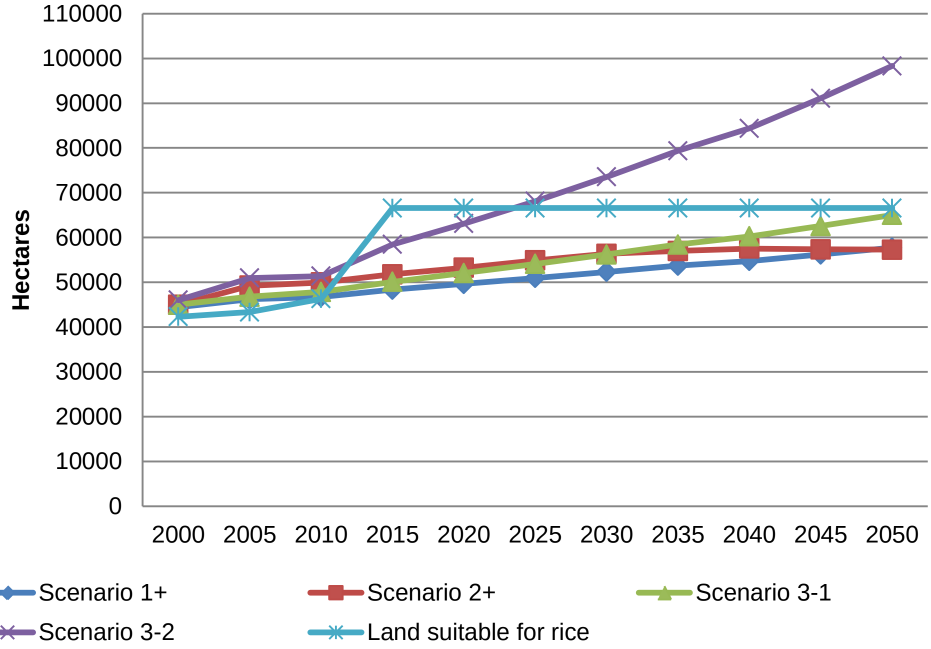
Studies point out the major influence of land and water productivity on overall food production. Papademetriou et al. (2000) applied a Crop Area Production Model to evaluate crop area demands by taking into account not only food demand and population change, but also levels of land and water productivity.

In 2008, land allotted for paddy rice cultivation was 66,582 ha (CNMC 2012). The MK 16 team estimated the increase in crop area demand for rice cultivation based on population changes and agriculture yield, defined in the scenarios below:

- Scenario 1+: Population growth rate specified in Scenario 1 (0.77%) and the annual yield growth rate is 1.20%;
- Scenario 2+:Population growth rate specified in Scenario 2 and the annual yield growth rate is 1.20%;
- Scenario 3: Population growth specified in Scenario 1 and constant yield at 1612 kg/ha; and
- Scenario 3-2: Population growth rate specified in Scenario 3 and constant yield at 1612 kg/ha.

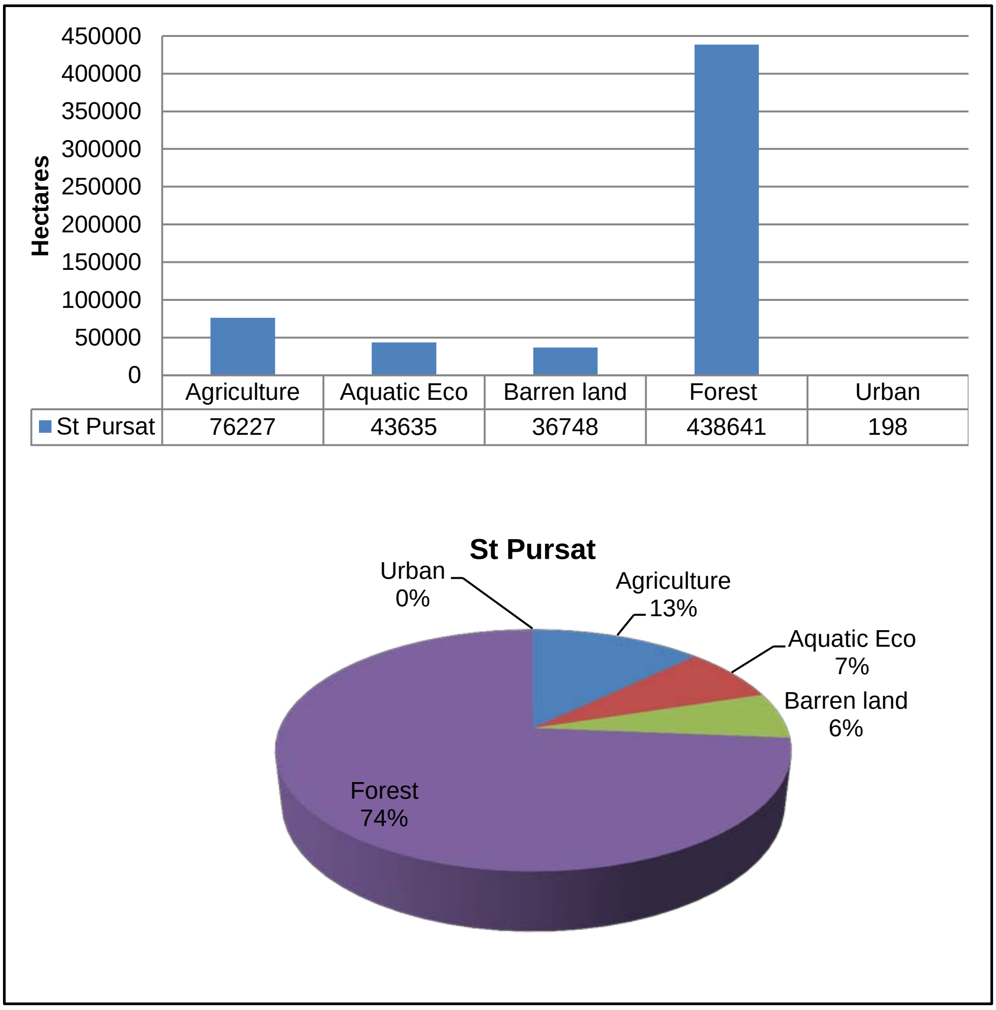
Figure 7 shows the increase in crop area demand in Pursat based on these scenarios. In a moderate Scenario 1+, demand for harvested area in Pursat will increase to around 60,000 ha by 2050 (an increase of 22%). In an extreme Scenario 3-1, demand for harvested area will exceed the reported land area suitable for paddy rice production by 2020. This scenario also predicts that by 2050, an additional 31,000 ha (32% increase compared to 2008 figure) will be required to produce the amount of rice needed for domestic consumption alone.

Figure 7 Projected increase in paddy field area in Pursat as compared against reported paddy area in 2008.



Rice expansion is constrained by the availability of appropriate land. Figure 8 shows the distribution of land in Stung Pursat. Whereas the total land area of the catchment is around 595,449 ha, only 13% of the land in Stung Pursat is considered arable (land suitable for agriculture, including areas cultivated for rice, annual crops, perennial crops, and village garden crops) (CNMC 2012).

Figure 8 Major Land Use and Ecosystems in Stung Pursat (CNMC 2012).



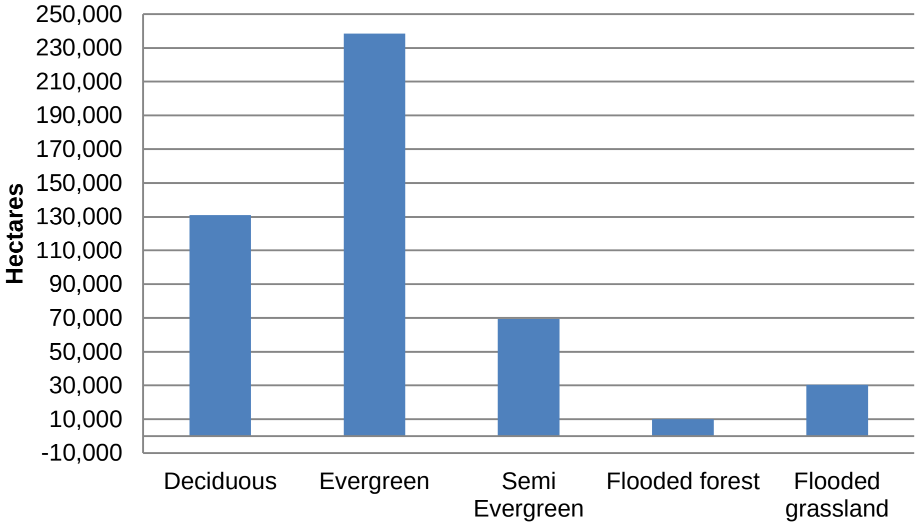
Pursat has some potential for paddy area expansion and production intensification. However, more substantial investments in affordable and reliable irrigation, extension services, transport infrastructure, and market access are required in order to meet Pursat's growing needs.

A number of other factors can influence the land area required for agricultural growth, including agricultural practices, climate variability and change, ecological constraints, remoteness, poor soil quality, land titling issues, water access, zoning laws/ limits (for economic and social concessions and infrastructure development), and human habitation (CNMC 2012; Pech and Sunada 2006). About 75% of the Stung Pursat catchment is covered by mountains and hilly areas with a land elevation of 30 m or more; these conditions may not be suitable for paddy rice production (Ashwell *et al*. 2011).

Barren land occupies about 6.2% of the total Stung Pursat land area. More than 99% of barren land consists of infertile soil, while rock-outcrop, saline soil, and sand bank round up the remaining portion (CNMC 2012). Therefore Pursat's potential for agricultural expansion is low in barren land.

Figure 9 demonstrates the type and distribution of forest area in Stung Pursat. There are few studies about the quality and quantity of forests, while the existing ones contain different definitions of forest and vegetation types. Even less work exists on the rate of forest decline and degradation, which makes it extremely challenging to quantitatively assess future trends in forest cover (Lang Ch 2001; ADB 2000; MRC 2003).

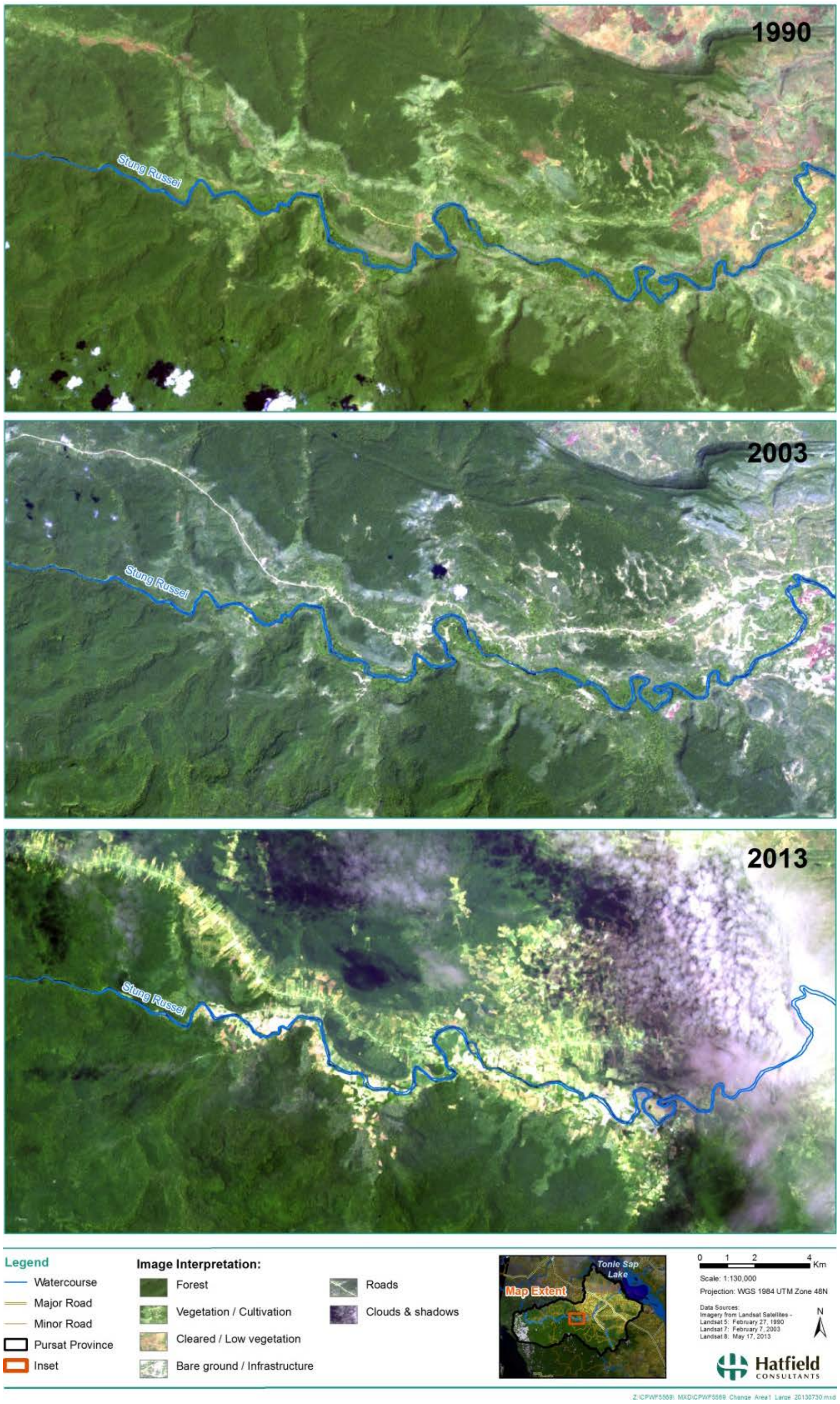
Figure 9 Major Forest Types in Stung Pursat (Data source: CNMC 2012 based on JICA 2006 report).



According to JICA (2011), evergreen forest covers over 238,478 ha of the land area in Stung Pursat. However, some forest areas and vegetation covers within the catchment have been awarded to large-scale agricultural and mining resource exploration and economic land concessions.

The *Land/Forest-use and Trends Analysis* report prepared as part of the "Fostering evidence-based IWRM in the Stung Pursat Catchment (Tonle Sap Great Lake), Cambodia project" discusses some of the trends, causes and consequences of land use changes in Pursat. This report provides Landsat images of five locations along the Stung Pursat in 1993, 2003 and 2013 to capture the change in forest/vegetation cover over the years. Figure 10 is one of the images from this report; the figure shows changes in land cover in the center of the Province, at Stung Russel, near the site of hydropower Dam No 1. The figure illustrates that change was greatest between 2003 and 2013.

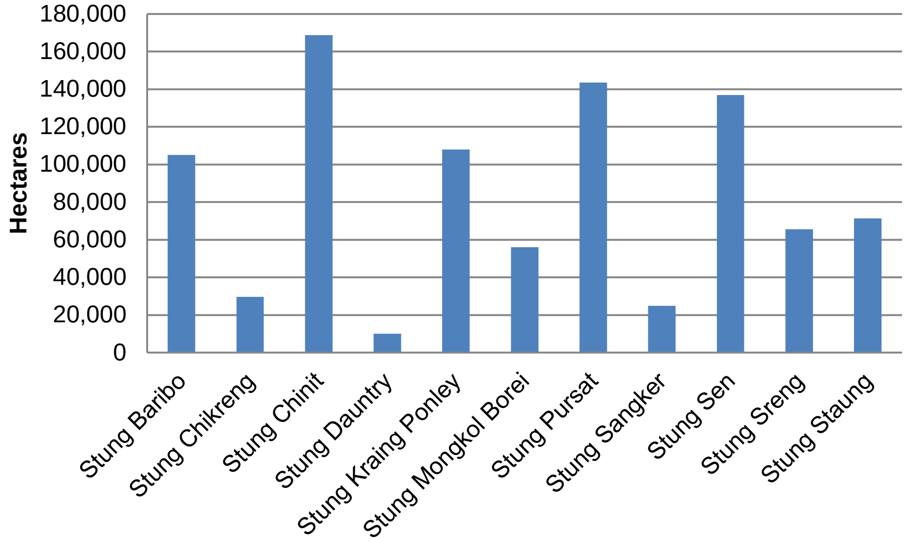
Figure 10 Using Landsat to monitor land cover changes in Pursat between 1990 and 2013.



According to the CNMC study (2012), the total area of land concessions in Pursat catchment is 143,509 ha. Amongst those catchments surrounding the Tonle Sap Basin, Pursat is second in terms of total area awarded to land concessions, as highlighted in Figure 11.

The pressures on land from population change and other factors are important to consider for planning and development work. The information presented here was also presented at the 2nd MSP session in Pursat.

Figure 11 Land Concessions in Key Tonle Sap Catchments (CNMC 2012 based on MAFF 2009 and MIME 2008 data).



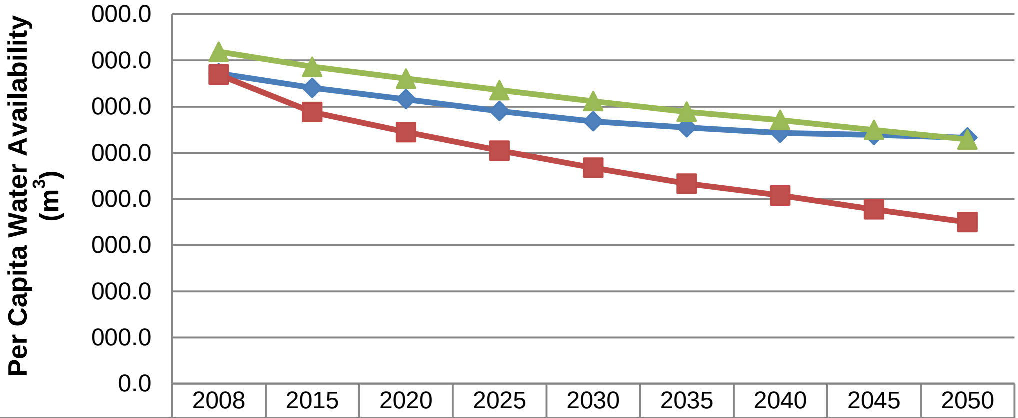
5.0 ASSESSMENT OF POPULATION GROWTH AND WATER AVAILABILITY ISSUES

5.1 LONG-TERM PER CAPITA WATER AVAILABILITY TRENDS IN MRB

Compared to other river basins around the world in term of actual renewable water resources per capita, Cambodia is not yet experiencing water stress. According to the World Resource Institute, a basin reaches "water stress" when per capita water supply is less than 1,700m^3/year (Revenga 2000). Cambodia's per capita water availability was about 8,374 m^3/year in 2000 (World Resource Institute 2006).

Theoretically, an average flow of 2,818 MCM/each year in Stung Pursat can serve the water requirements for all of Pursat (CNMC 2012 and JICA 2011). Based on population scenarios defined in Section 2.2, the MK 16 team estimated long-term trends in per capita water availability (Figure 12). As apparent from the figure below, Stung Pursat's per capita water availability for 2008 was similar to the average national per capita water availability (over 6,650 m^3/year). For Scenario 3 (constant population growth at the national average rate), Pursat will come closer to a "water stress" situation when per capita water supply reaches approximately 3,400 m^3/year.

Figure 12 Long-Term Trends of Per Capita Water Availability in Stung Pursat.



	2008	2015	2020	2025	2030	2035	2040	2045	2050
Scenario 1	6718.1	6405.09	6156.75	5901.63	5678.48	5546.9	5431.88	5384.34	5325.5
Scenario 3	6691.5	5880.43	5447.83	5047.05	4675.75	4331.78	4074.9	3775.13	3497.4
Scenario 2	7185.52	6862.31	6604.11	6355.62	6116.48	5886.34	5708.48	5493.69	5286.98

The situation depicted in Figure 12 does not take into account the variation in the distribution and access to water in Pursat. Several issues of concern exist, including:

- Water shortages exist in downstream parts of the catchment and high turbidity during dry season, especially during drier years for most downstream stretches;
- Most parts of the catchment experience floods and drought; and
- Intensification of competition for resources within and across the catchments (1st MSP, January 24-25, 2013).

Water issues are closely related to the unequal spatial and temporal distribution of flow. The issues are likely to intensify or escalate further in the future as population and water use/diversion increases in Pursat.

5.2 ASSESSING HYDROLOGICAL IMPACTS DUE TO IRRIGATION

Many large-scale economic activities are at various stages of planning and development in the Stung Pursat. Development and operation of major hydropower, infrastructure, and increased irrigation systems and water diversions exert numerous positive and negative impacts on the communities and natural resources.

This section examines the scope for balancing water availability and demand for water for food production under different assumptions about demographic trends and related food demand in the Stung Pursat. We attempt to describe the irrigated agriculture water demand and its likely impacts on hydrological changes. Focus on irrigation water demand for paddy production is kept, because rice is the most water-intensive crop and will remain the stable food source for most of the population – rich or poor – in the Mekong River Basin (FAO 2005).

At present, agriculture across the basin consists mainly of subsistence production. Gradually, however, commercialized agriculture production and an increased dependence on market inputs, such as fertilizers and pesticides, machinery and advanced seed varieties, can be expected. Agricultural expansion and intensification, especially for dry season irrigation, will mean higher demand for water (CNMC 2012).

Understanding actual irrigation water use is difficult, given the gaps in required data. An estimate can be made based on water requirements for producing a certain quantity of food (called water unit requirements). This includes not only the blue water (irrigation water withdrawal), but also water from soil moisture. Estimated irrigation water demand is based on the projected growth in food demand due to population growth, divided by the assumed water unit requirement for producing a kilogram of paddy rice or irrigate one hectare of paddy field during different cropping seasons (Papademetrieu 2000).

Table 5 lists the irrigation water demand for an average production of 1 kg of paddy rice or equivalent, using current irrigation techniques, and based on crop yield in 2000 for various Mekong countries.

Table 5 Rice Crop Production by Season in Mekong Countries (Papademetrieu 2000).

	2000 Crop yield (kg/ha)	Water unit requirement (m^3/kg)
Yunnan	4869	3.7
Myanmar	3082	4
Laos	2978	4
Thailand	2,600	4
Cambodia	2150	4
Vietnam	4075	3.7

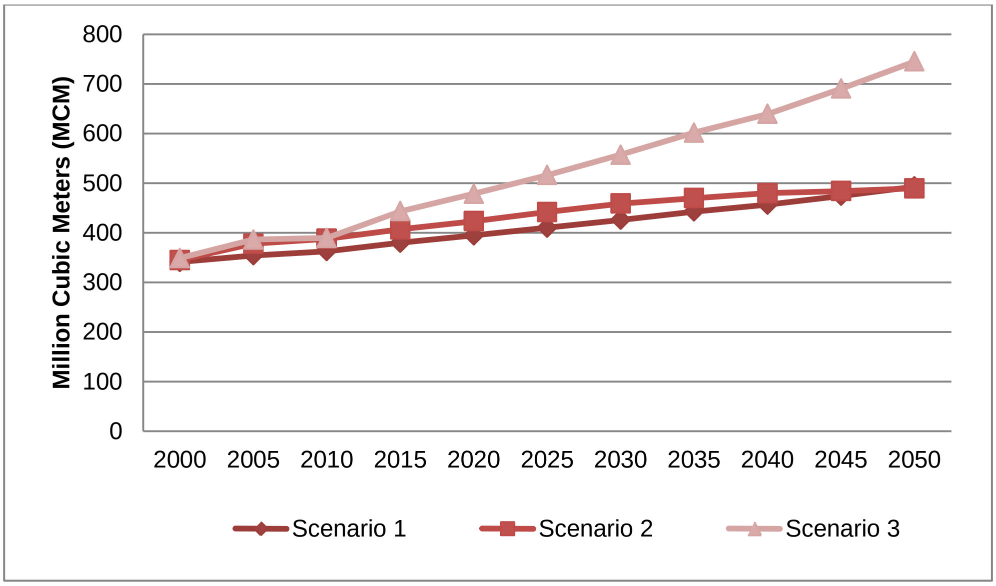
This water and rice production ratio is modest compared to our findings[3]. In this study, we use the average water demand of 4.7 m^3/kg of paddy.

In 2000, irrigated agriculture use accounted for around 16% of the annual average discharge of 2,818 million MCM (JICA 2011). This number agreed with the Mekong River Commission (MRC) study that estimated approximately 80–90% of the total water abstraction for irrigation from the Mekong River is two forms: blue water - receding flood water storage, diversions from streams and from ground water sources; and, water from precipitation (soil moisture) (BDP 2003).

[3] See, e.g., Falcon T., 2000, which shows that water and rice ratio is different under different ecological conditions; 6.5 m^3/kg for rain-fed upland; 4 m^3/kg for rain-fed low land and irrigated upland; and 3.7m^3/kg for irrigated low land/deep water paddy.

Figure 13 presents the projected irrigation water demand in Stung Pursat calculated by the Mk 16 team. The figure shows that in Population Scenario 3, the irrigation water use will account for significant annual discharge of the Stung Pursat by 2030 and 2050.

Figure 13 Projected Total Irrigation Water Demand in Stung Pursat.



However, this figure neglects the uneven distribution of water flow over time (wet and dry seasons, wet years and dry years, critical dry months, etc.) and space (upstream, downstream, location near or far from water sources, etc.). There are severe fluctuations between: flow in wet and dry seasons; flow in wet and dry years; water quality and suitability for beneficial water use; and, water availability in one geographic area or another. In addition, a portion of total runoff needs to be retained for other uses, like for aesthetic/recreational and ecological purpose (Revenga 2000). Demands for other water uses, such as domestic water supply and sanitation and industry will also increase in the coming years.

During dry years, the need for irrigation is especially important. Withdrawal of water by upstream communities and other catchments will decrease water availability in downstream communities, especially in critical dry season months. There is a need for proper maintenance and release of the flow from upstream, flow regulation and storage, and optimization of dry season irrigation (through raising water productivity, increased utilization of less water-consumptive crop types, adapting cropping calendars, etc.). All these initiatives will require stronger cooperation for water and benefit-sharing and securing flow.

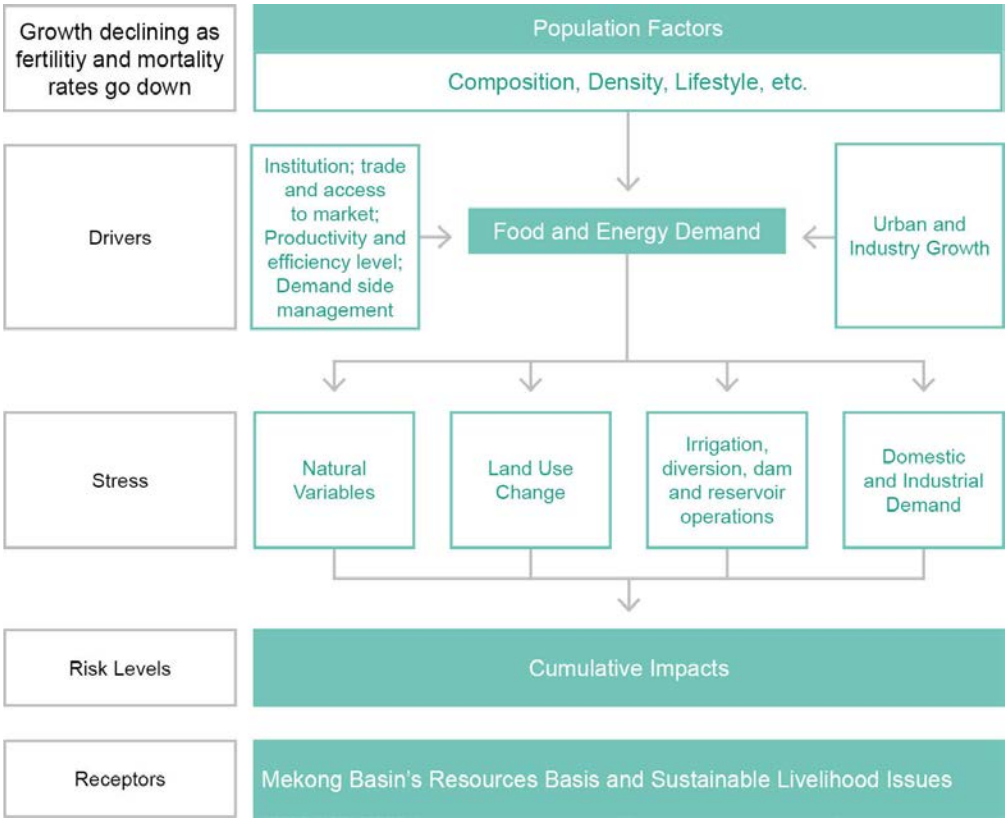
5.3 CUMULATIVE IMPACTS FROM HYDROPOWER AND IRRIGATION AT KEY LOCATIONS OF THE CATCHMENT

Cambodia's national strategic development objectives include alleviation of those experiencing poverty, economic growth, and development of water and water-related resources, amongst many others (NDSP 2009-2013). A number of large-scale development projects are at various stages of planning in the Mekong Sub-region. This warrants a closer look at the demands and valuations (benefit and cost) for key water-related economic activities such as irrigated agriculture, hydropower, fisheries, wetlands, flood mitigation, navigation, tourism, and municipal and industrial water supply.

Figure 14 takes into account the acceleration in food and energy production (water-based), which is required not only for meeting growing domestic needs, but also for meeting growing export targets for economic development.

Integrated planning and development of water and related resources involves taking into account multiple stresses, magnitude of risks/vulnerabilities and multiple risks/degrees of vulnerabilities. An approach such as this would allow planning to take into account both cross-sectoral implications of development interventions, and their likely impacts on high-value natural resources and socially-vulnerable populations at the earliest possible stage of planning. For example, hydropower projects have implications for: fisheries and agriculture; forest cover and land use changes (which reciprocally affects run-off patterns, sedimentation, and erosion); and, people's livelihoods and economic activities (World Bank & ADB 2006).

Figure 14 Generalized Impact Linkages Model of Population, Demand Change and Resources Base (Pech and Sunada, 2008)



Assessing c**umulative effects is** an approach which allows for the impacts of several policies, plans, programmes or projects to be assessed in a systematic manner. Individual developments on their own are perhaps insignificant in terms of impacts, but when they are considered in conjunction with impacts from other developments in past, present and future scenarios, this may result in significant incremental effects. It is important to focus on the effects – individual or cumulative – on water levels, flows and other characteristics at different downstream stretches of the river mainstream due to hydropower development, expansion of agricultural irrigation, and water diversions.

The activities and developments examined in this study are those that are of most relevance/concern to the sustainable development and protection of the water and related resources of the Stung Pursat. Based on the hydrology of the Stung Pursat, where water demand is higher in the dry season and water availability is far below the average flow, it is important to adopt approaches in assessing water demands and availability at time-scales more refined than annually (monthly) and at key locations of the river.

The *Water Demand Analysis within Pursat river catchment* report, prepared for the MK 16 project, assesses the impacts of existing and planned hydropower and irrigation expansion projects in Stung Pursat catchment. Figure 15 presents a flow chart for the main developments in the Stung Pursat catchment.

In the *Water Demand Analysis within Pursat river catchment* report report, water balance calculations were conducted using two water development scenarios:

- Dam scenario: In 20-years, all simulated flows were used directly as input flows to the three dams - Dam 1, Dam 3, and Dam 5 – and the computed outflows from the dams were used as input flows to the systems. Whereas Dam 1 is in the planning stages and will provide hydropower only, Dams 3 and 5 are multi-purpose and have been under construction since 2010.

- Natural scenario: In 20-years, all simulated flows were treated as natural flows. The three dams existing and planned dams described below were excluded.

The Water Demand Analysis within Pursat river catchment report used information related to:

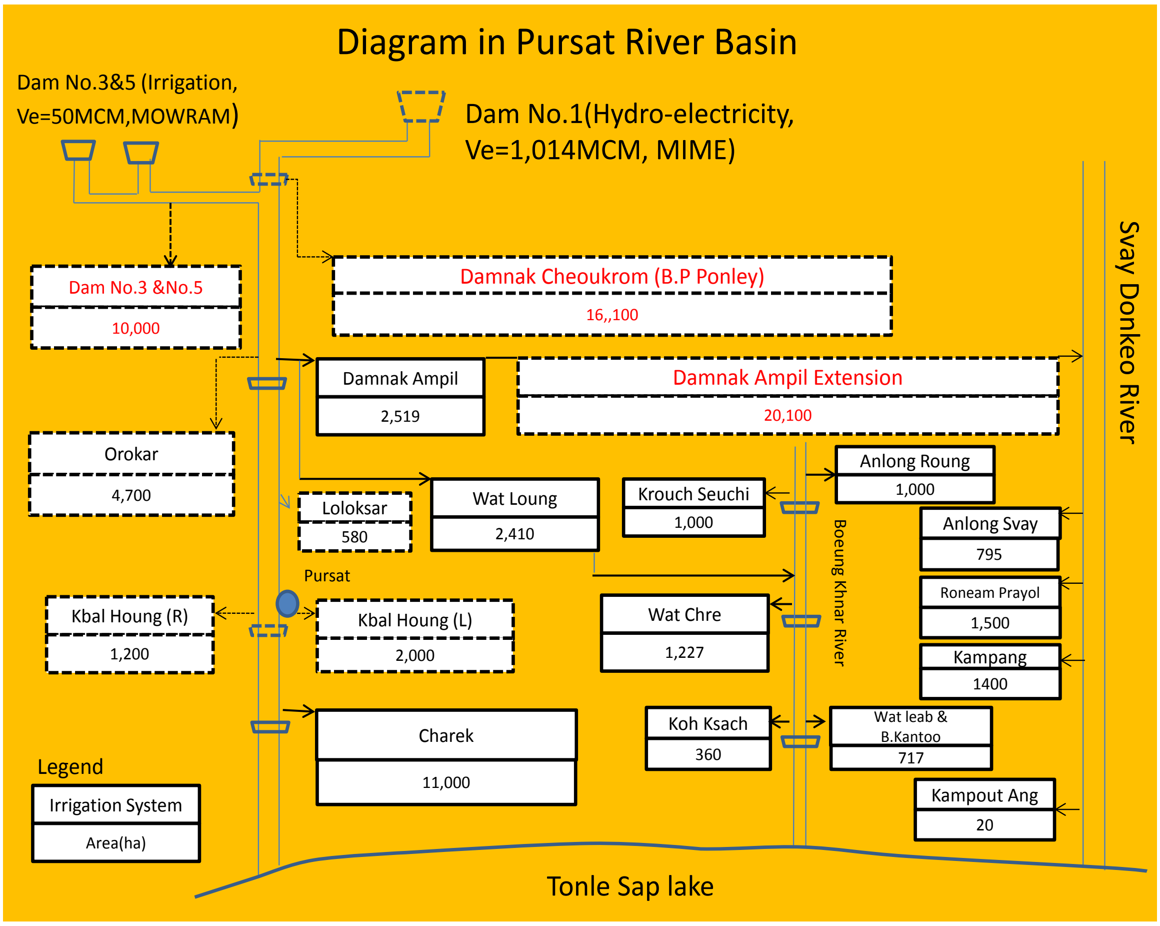
- Water demands for irrigation and other purposes;

- River runoff taking into account the three dam development projects (dams No. 1, 3, and 5, which are all in existence or planned);

- Available water used by existing and planned water resources facilities and irrigation systems in the basin; and

- Areas defined as vulnerable and prone to flooding.

Figure 15 Water resources development in the Stung Pursat Catchment (JICA 2011).



5.3.1 Water Supply for Irrigation Schemes Under the Natural and Dam Scenarios

Results from the water balance simulation revealed that water supply under natural flow conditions (i.e., absence of Dams No. 1, 3, and 5) would support 55,509 ha of irrigation schemes in the Stung Pursat. In this scenario, flow would not support additional irrigation schemes in the neighboring catchments of the Svay Donkeo and Beung Khnar rivers. When Dams No. 1, 3, and 5 were introduced in the simulations the additional water stored in these impoundments would be sufficient to support all existing and planned irrigation schemes in the Stung Pursat, Beung Khnar, and Svay Donkeo catchments.

5.4 CUMULATIVE IMPACTS OF SCENARIOS ON HIGH FLOW CONDITIONS

In the Stung Pursat, floods are an annual phenomenon. Flood season in both the mainstream and tributaries is between June or July and Oct or Nov, during which 85-90% of total annual water volume flows through the rivers. Although providing many benefits, abnormal floods can cause severe damage to the economy, people's lives and their livelihoods. In recent years, abnormal flooding occurs at a higher frequency and its devastating effects are greater. The risk of devastating floods is on the rise, due to both man-made and natural causes. At the same time, environmental benefits from floods are better understood and documented, particularly in terms of environmental conservation, fisheries and other natural resources (Pech, 2003).

5.5 FISHERIES FUTURE DEMAND AND SUPPLY: THREAT TO FOOD SECURITY

Fish and rice are essential elements in food security for Cambodia and the Mekong region. The Tonle Sap Basin (TSB) supports one of the most productive freshwater fisheries in the world, with annual yields of 230,000 metric tons (1995-1996), equivalent to about 60% of the country's total annual fish catches (Van Zalinge, 2002) Over 500 fish species have been described for the Mekong system in Cambodia, and about 200 species are reported to be found in the TSB (Pech *et al.*, 2008) Some of the species found in the Tonle Sap Great Lake remain there permanently, while many other species use the Great Lake and its floodplains only temporarily and migrate back to the Mekong River at the end of the rainy season. From over 200 fish species in the TSB, only about 10 of them dominate the annual fish catches (Van Zalinge *et al.*, 2003 and Van Zalinge, 2002). The photos below (Figure 16) show some examples of different fisheries resources in Pursat.

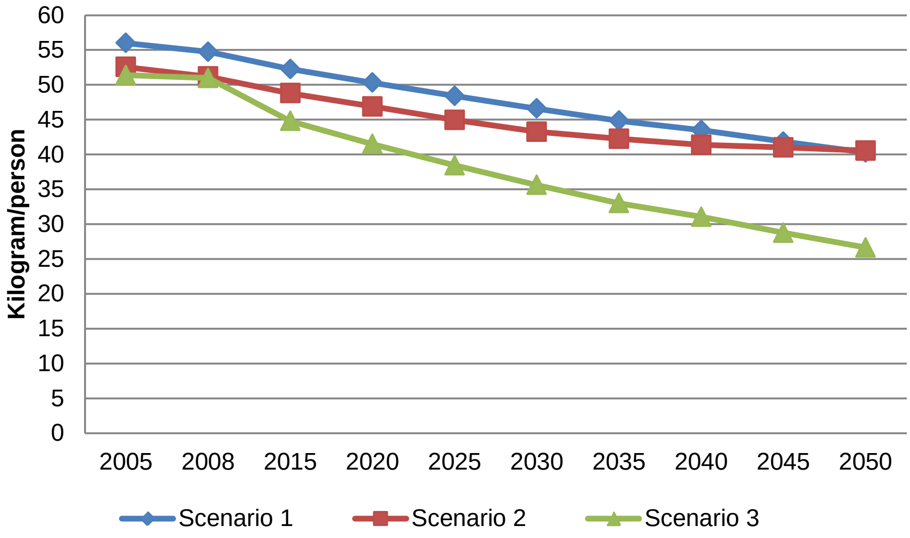
Figure 16 Fisheries in Pursat Province.

(From left): snake head representing "black fish species"; # 2 and 4: Trey Real (also known for Cambodian currency) the main migratory fish species, and # 3: "white fish species" (Pech *et al.* 2008)

The fisheries resources available to villagers in Pursat are dependent upon the local topography – mainly in the floodplain from the main road (National Road 5) down towards the Tonle Sap Lake. There have been numerous debates about whether current fisheries resources will be enough to meet the growing demand for affordable protein and income generation. There are currently no available data on annual fish catches in Pursat. A MRC study found that the average consumption of freshwater fish in the Mekong Basin is approximately 56 kg/person/year (Mekong River Commission 2002). Actual consumption varies from 10 kg/person/year in mountainous areas to 89 kg/person in the Cambodian flood plain (Baran 2005). Based on the 56 kg/person/year estimates, the total consumption in Pursat (2005) would be estimated at approximately 21.5 million kg/year.

Figure 17 assumes that catch rates remain constant between 2005 and 2050 and shows a declining trend in per capita fish consumption, as population increases. This figure is also created based on the population scenarios in Section 2.2. The figure shows that average per capita fish consumption in Pursat would decrease by 28 to 48% depending on the population growth scenarios applied (Population Scenarios 1, 2, or 3). The substantial reduction in this highly affordable source of animal protein would have drastic effects on low-income and subsistence populations. While aquaculture is expected to make up for some of this shortfall, aquaculture development is limited by available technology and extension services, financial constraints, and environmental issues. For example, expansion of aquaculture can contribute to environmental degradation when mangroves are cleared for pond systems, as is currently the case in the Mekong Delta (CEMARE, 2002). From a food security perspective, and given the high dependency of large numbers of people on aquatic resources for their livelihoods, declining fish availability per capita is likely to have a severe impact on the poorest households.

Figure 17 Projected decline in per capita fish consumption for three population scenarios assuming 2003 catch levels.



5.5.1 Impacts on Fish Productivity

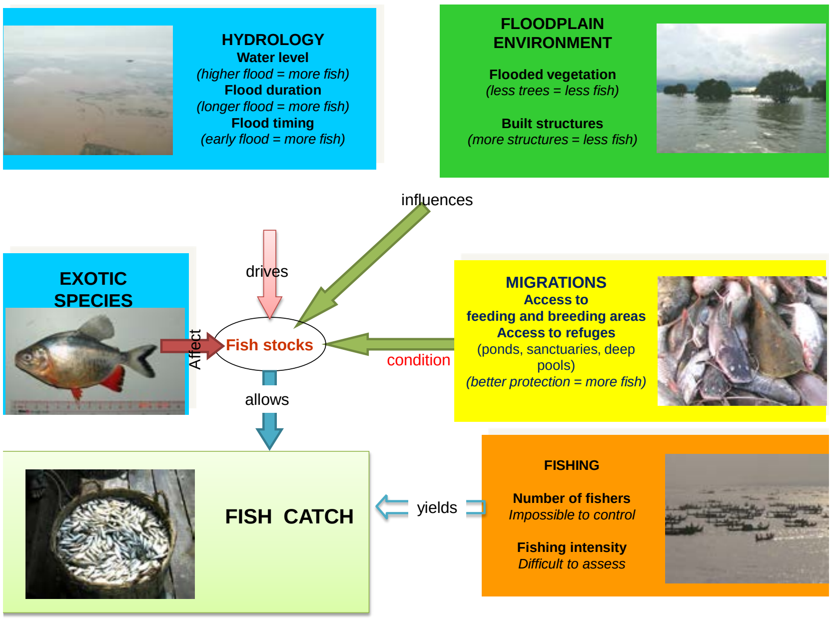
Figure 18 illustrates some of the many factors influencing fish stocks in the Mekong. According to various studies (Baran 2005; Sarkkula & Koponen 2003; Ian *et al*. 2003), the high productivity level of Mekong fisheries depends on a combination of different factors, including:

- Hydrology (water level and quality, flood duration and extent, flood timing and natural fluctuation);
- Habitat (type of inundated forest/vegetable, land cover, dry season refuge and turbidity);
- Biology (fish migration route/access); and
- Fishing practices and management.

Among the threats that can be listed are (Pech and Sunada 2006):

- The destruction of spawning grounds or dry-season refuges by habitat alterations (for example, river bed blasting, dredging, removal of rapids or siltation, and removal/alteration of vegetation);
- The construction of dams, weirs or diversions, which act as physical barriers to fish migrations, and substantially affect natural flow patterns and flood extent; and
- Changes in the quantity and quality of water available for sensitive habitats and the timing of hydrological events, and pollution from industry, agriculture and urban development (Pech & Sunada 2006).

Figure 18 Factors driving Cambodia Inland Fisheries Production (Chheng Phen [FIA 2012], Personal Communication, 2012).



A study by World Fish Center and Fisheries Administration (FiA) (Arthur *et al.* 2006) found that Pursat was the site of many proposed developments, including irrigation canals, roads and construction projects that intend to divert or retain water. These developments could have significant hydrological effects on natural river systems.

However, the hydrological regime is the most important mechanism affecting fish ecology and productivity (Baran 2005; Pech *et al*. 2008). Evidence underlines the importance of a cross-sectoral and cross-boundary management of the fishery and other sectors both in Cambodia and other riparian countries. Any river basin development measures that would substantially lower or even delay annual flooding will have negative impacts on the TSB and MRB fish production (Pech & Sunada 2006).

6.0 CONCLUSIONS

Pursat has sizable water and related resources to support current livelihood needs and economic development. Anticipated demographic changes in Pursat will create opportunities and challenges for the province in meeting the rising water and food demands from various stakeholders. The role of policy makers and institutions is critical in allocating water fairly and adequately in the province to achieve food and water security. In doing so, the factors presented in Table 6 are important to consider.

Table 6 Important considerations for policy making in Pursat Province, Cambodia.

Factors	Explanations/ Recommendations
Potential created by demographic dividend	Demographic change in Pursat is creating challenges related to meeting greater resource demands, as well as solutions (e.g., increasing youth demographic, increasing human resources available to address issues). Policies can help in capitalizing on the opportunities resulting from predicted population dynamics in Pursat.
Socio-economic factors (income, land possession) that distribute risks of water and food security	Unequal resource distribution and lack of affordability experienced by some low-income groups prevent them from meeting basic livelihood needs, not necessarily and as clearly defined as a lack of food. Policy makers must identify and address the needs of vulnerable community members.
Natural disasters and changes to water availability	Climate change, variation and natural disasters are contributing to temporal and spatial changes in water availability in Pursat and in the country. These changes must be studied in more detail, and their impacts factored into decision-making regarding development and use of water resources.
Population pressure on Pursat's resources	Due to population growth, demand for food, land, water, and fisheries will increase in the Pursat catchment. Demographic change can be managed by resource policies that meet the demands of the growing population in an ecologically sustainable manner.

Table 6 (Cont'd.)

Factors	Explanations/ Recommendations
Temporal and spatial variation in water availability throughout the province	Seasonal (temporal) and spatial changes in water availability affect livelihoods in Pursat. For example, in the dry season, downstream communities are greatly affected by alterations in the flow of water upstream. Water allocation policies must consider the inter-dependencies and the potential conflicts among the downstream and upstream water communities. This study also recommends that modeling of water flow during dry season (and other critical periods) should be conducted covering water storage, diversion and release to plan for water allocation along certain stretches of the Pursat.
Changes in land use and the limits of arable land expansion	Since 2000, land-use change in Pursat has been considerable (*Land Use and Trends Analysis* report). Furthermore, factors like remoteness, poor soil quality, land title issues, distance from water access and markets, infrastructure expansion, and industrial land concessions constrain the area of land that is available for agricultural expansion. A study of land suitability, irrigation viability (cost and access), and market price and access should be completed in order to guide policy makers. This study found that Pursat will have to increase paddy production and develop an effective food security policy to meet future predicted population growth. While there is potential for paddy area expansion and intensification, substantial investment in affordable and reliable irrigation, extension services, transport infrastructure and market access is needed.

7.0 CLOSURE

We trust the above information meets your requirements. If you have any questions or comments, please contact the undersigned.

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