MEKONG RIVER COMMISSION

THE COUNCIL STUDY

The Study on the Sustainable Management and Development of the Mekong River Basin, including Impacts of Mainstream Hydropower Projects

Thematic Report on Impacts of Non-Irrigated Agriculture Development and General Trends in Major Land-Use Categories in the Lower Mekong River Basin Including Recommendations for Impact Avoidance and Mitigation Measures

(Unedited Version)

22 January 2018

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The MRC is funded by contribution from its member countries and development partners of Australia, Belgium, European Union, Finland, France, Germany, Japan, Luxembourg, the Netherlands, Sweden, Switzerland, the United States and the World Bank
Suggested citation:

Koponen, J., Paiboonvorachat, C. and Munoz, A. (2017). The Council Study: Study on the sustainable management and development of the Mekong River, including impacts of mainstream hydropower projects. *Thematic Report on Impacts of Non-Irrigated Agriculture Development and General Trends in Major Land-Use Categories in the Lower Mekong River Basin Including Recommendations for Impact Avoidance and Mitigation Measures.* Mekong River Commission (MRC), Vientiane, Laos PDR. 128 pp.

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Abbreviations and acronyms

AIP	:	Agriculture and Irrigation Programme (of the MRC)
AquaCrop	:	FAO state-of-the-art physiological crop model
BDP	:	Basin Development Plan
BDP2	:	BDP Programme, phase 2 (2006 –10)
BDS	:	(IWRM-based) Basin Development Strategy
BioRA	:	Biological resource assessment team (under Council Study)
CCAI	:	Climate Change and Adaptation Initiative (of the MRC)
CIA	:	Cumulative Impact Assessment
CNMC	:	Cambodia National Mekong Committee
CS	:	Council Study
DMP	:	Drought Management Programme (of the MRC)
DSF	:	MRC Decision Support Framework based on hydrological, water resources and hydrodynamic models
EP	:	Environment Programme (of the MRC)
FAO	:	Food and Agriculture Organisation
FMMP	:	Flood Mitigation and Management Programme (of the MRC)
FP	:	Fisheries Programme (of the MRC)
HH	:	Household
IQQM	:	Integrated Quantity and Quality Model
IBFM	:	Integrated Basin Flow Management (MRC study)
IFAD	:	International Fund for Agricultural Development
IKMP	:	Information and Knowledge Management Programme (of the MRC)
ILO	:	International Labour Organisation
IWRM	:	Integrated Water Resources Management
IWRM-model	:	Modelling framework integrating DSF, SOURCE and WUP-FIN for socio-economic and environmental indicators
ISH	:	Initiative for Sustainable Hydropower (of the MRC)
JC	:	Joint Committee (of the MRC)
LMB	:	Lower Mekong Basin
LNMC	:	Lao National Mekong Committee
M&E	:	Monitoring and evaluation
MRC	:	Mekong River Commission
MRCS	:	Mekong River Commission Secretariat
MRC-SP	:	MRC Strategic Plan
NMC	:	National Mekong Committee
NMCS	:	National Mekong Committee Secretariat
NAP	:	Navigation Programme (of the MRC)
PMFM	:	Procedures for Maintenance of Flow on the Mainstream
PWUM	:	Procedures for Water Use Monitoring
SEDB	:	Socio-economic database (of the MRC)
SIMVA	:	Social impact Monitoring and Vulnerability Assessment (conducted by MRCS)
SoB	:	State of Basin report (of the MRC)
SocEc	:	Social Assessment team (of the Council Study)
SWAT	:	Soil and Water Assessment Tool, hydrological and water quality model
TCU	:	Technical Coordination Unit (of the MRCS)
TNMC	:	Thai National Mekong Committee
UMB	:	Upper Mekong Basin
UN	:	United Nations
UNDP	:	United Nations Development Programme
VNMC	:	Viet Nam National Mekong Committee
WUP-FIN	:	MRC Water Utilization Program Finnish component

Document History

Version	Revision	Description	Issue date	Issued by
1	0	Interim Report	Nov 2016	Prasong, Koji, Cong
2	0	In addition to Interim Report, the team added the scope of assessment and assessment outline, explained data quality and availability, summarized main scenario data for LMB, defined assessment indicators and methodology, improved the report outline.	15. Mar 2017	Jorma
2	1	Added sub-scenario description and assumption. Summarized of forest and agricultural areas used for sub-scenario	27 Apr. 17	Chamaporn
3	0	Formatted Interim Report; Added results for land use change mapping and agricultural modelling	20 June 2017	Jorma, Andres
3	1	Formatted Interim Report; Added results for land use change mapping and agricultural modelling	20 June 2017	Jorma, Andres
3	2	Updates including text revisions, further results for main scenarios, figure updates and sub-scenario results	15 August 2017	Chamaporn, Andres, Jorma
4	0	Addition of sub-scenarios and discipline team inputs	11 November 2017	Chamaporn, Andres, Jorma
5	0	Report revision based on the Member Country and MRCS Planning Division questions and suggestions.	16 Jan 18	Chamaporn, Jorma
5	0	Report revision based on the Member Country and MRCS Planning Division questions and suggestions.	22 Jan 18	Chamaporn, Jorma

1 Executive summary

Council Study Agriculture and Land Use Thematic Area has made substantial strides forward in terms of land use GIS data processing, scenario definitions and implementation and integrated methodology connecting the thematic work to the triple bottom line assessment and modelling.

Land use change is potentially one of the main factors impacting natural conditions and people's livelihoods. The estimated agriculture changes in the upstream Kratie part of the basin are small and consequently have marginal impact on flow and sediment loads as well as ecological conditions. In contrast Cambodia is experiencing rapid expansion of agriculture but modelling other than for irrigation has not been applied there. Another information gap is involved with fertilizer and other agro-chemical use that needs to be filled in the future with monitoring and modelling data.

Food security will decrease in the future scenarios for some Lao PDR areas and for Cambodia. This is mostly because of population growth and can become acute for specific flood and drought events. Driest climate change scenario C3 needs to be highlighted here.

Hydropower development has by far the largest impact on agriculture through water availability, flow and flooding, salinity and fertile sediment input to the agricultural areas. The impacts are both positive and negative. The positive impacts include improved water availability, mitigation of flood peaks and flood damages, increased dry season flow and decreased salinity intrusion. The negative impacts include decreased fertile sediment input to the floodplains and fields that need to be mitigated.

Climate change has obvious risks involved especially if drier climate projections are realized. Modelling shows that in the assessment corridor Tonle Sap surroundings are quite sensitive to drier climate.

2 Background

Agriculture is a very important sector within the Lower Mekong Basin (LMB). Farming is the primary occupation of the rural areas within the LMB in each country. Between 2011 and 2014, the numbers engaged in farming have increased in Cambodia, Thailand and Viet Nam by on average 9% to 6.9 million, whereas the total number of farmers in Lao PDR has appeared to decline from 238,000 to a little over 15,000. The most important secondary occupation is farm labor, again reflected in all four countries, which had apparently increased by 485% between 2011 and 2014 to 18.6 million. Both primary and secondary important occupations confirm the importance of agricultural sector to generate household income.

Agriculture is the dominant water-related sector, particularly in Thailand and Vietnam whereas agriculture in Cambodia and Lao PDR is currently less intensively developed. In the whole LMB, the dry-season irrigated area of about 1.2 million hectares is less than 10% of total agriculture area. The expansion of irrigation is limited by the availability of dry season water flow and investment capacity.

During the past decade, agricultural land has been changed with some following trends: (i) expanding agricultural area: some areas have become cultivation land from bush forest after land clearing for agriculture and improving agriculture facilities especially irrigation development, (ii) crops and crop pattern have been changed: due to the improvement of irrigation, technology and market orientation, farmers have changed crops and crop pattern. In some rice areas, one annual rice crop is changed to two rice crops per year because of the irrigation development; (iii) in some area, agriculture land is degraded so that crop cultivation is not effective, therefore the farmers let these lands to be fallow; (iv) agricultural land has been changed into other use purpose depending on social-economic development. For example, these kinds of land would be for hydropower projects, industrial zone, resident’s area and transportation etc.

The change of agriculture land has transboundary impact; hence they need to be monitored. Firstly, these changes lead to change in water allocation for agriculture itself and for other purposes. Sustainable water allocation in the whole region and sub-basin needs the information on the agriculture development. Secondary, the ensuring food security depends on agriculture activities. Agricultural land use change needs to make sure to supply enough food at different scales. On the other hand, agriculture is main livelihood of the local farmers; therefore, it needs to be monitored to identify opportunities and risks to local farmers to seek timely adaptive solutions. Furthermore, the land use change has transboundary impact on the hydrology process and sediment transportation. They affect directly to other important social-economic sectors such as fisheries, navigation etc.

In general, land use change may have positive or negative impacts at multi levels of the basin on environment and local people livelihood, land use change needs to be monitored to understand the change and its impacts to the basin.

The most recent available population figures (2008-2012) shows a total population of 64.8 million people living within the LMB. Compared to the previous estimate of 60.6 million, based on the 2005 Census (Lao PDR) and 2008 Census (other LMB countries), there has been an apparent population increase of 9%. Earlier population data showed a 14% population increase from 1995-2000 to 2—5-2008. The most populous provinces are found in Thailand, Viet Nam and on the floodplains in Cambodia.

The rural population in Cambodia is projected to remain stable around the current level of 10 million people, while population growth will occur in cities. In Lao PDR, the rural population is projected to decrease somewhat as cities grow and absorb the population growth. There has been a decrease in the total rural populations in Thailand and Viet Nam and this is projected to continue.

Between 1990 and 2010, the economies of Viet Nam, Cambodia and Lao PDR experienced rapid structural changes with a significant reduction in the proportion being contributed by agricultural sector to national GDP, and a notable rise in the proportions being contributed by the industrial and service sectors. In Viet Nam, the contribution of the agricultural sector fell from 39% in 1990 to 19% in 2010. Although the economies of Cambodia and Lao PDR are primary based on transformation occurred in the 1970s and 1980s so, by 1990.

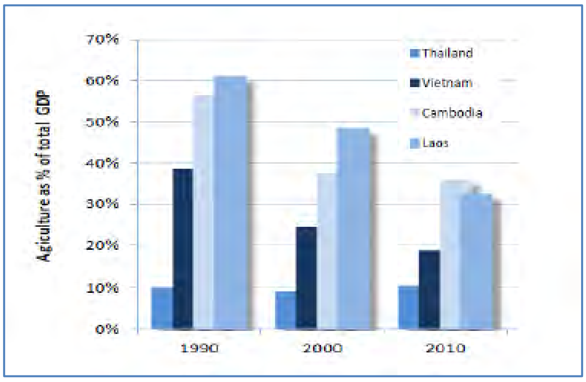


Figure 1: Agriculture ratio to GDP for the LMB countries

3 Current Sector Status

The data from Member Countries shows that the total rainfed harvest area for rice in the LMB is larger than the total irrigated harvest area for rice in 2013. Within the LMB, Mekong Delta in Viet Nam is the largest irrigated area for rice cultivation. Cambodia, Lao PDR, and Thailand have still large potential to be irrigated. Table 1 shows rice harvest area in 2013 in MCs.

Table 1: Rice harvest area in 2013 in MCs

Rice harvest area in 2013		
	Irrigated Harvest area (ha)	Rainfed Harvest area (ha)
Cambodia	483,446	2,485,521
Lao PDR	92,340	683,125
Thailand	598,805	6,312,846
Viet Nam	4,569,400	-
Total	5,743,991	9,481,492

The production of rice under rainfed condition in the LMB is mostly subsistence farming especially in Thailand and Cambodia. It totaled 22 million tons in 2013, with Thailand and Cambodia accounting for 13 million tons and 6 million tons respectively.

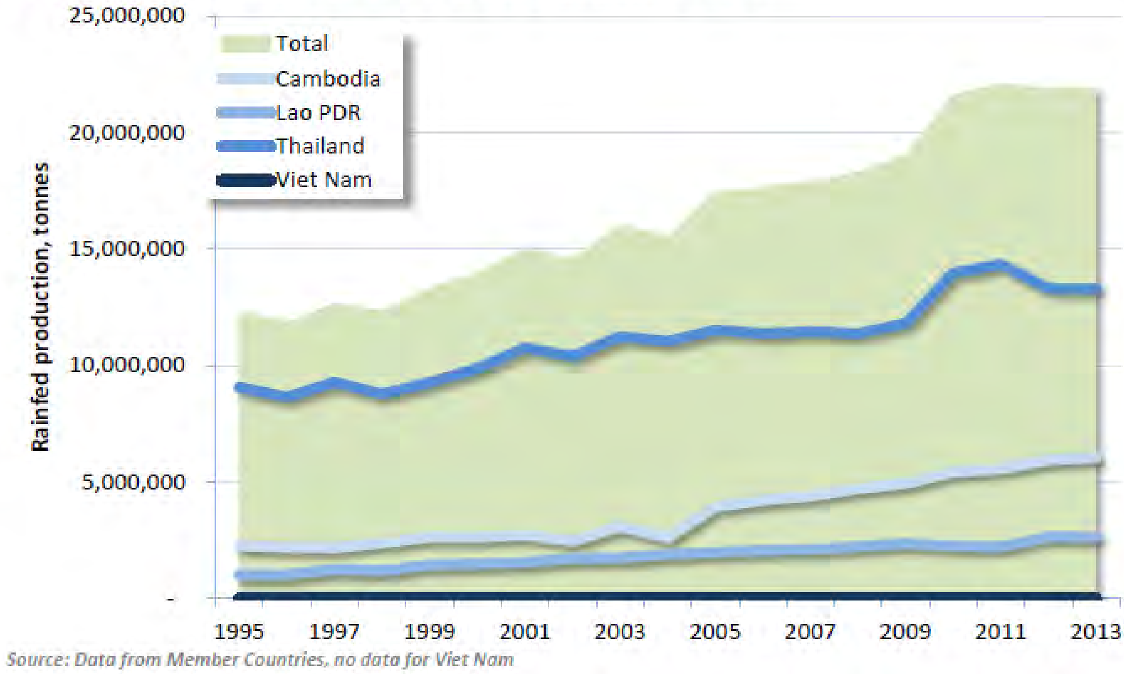


Figure 2: Past trends in rain fed rice production in LMB

The area and production of rainfed maize have been increasing in Cambodia, Lao PDR and Viet Nam, but have been decreasing in Thailand. In 2003, the overall area of rainfed maize in the LMB was estimated at 0.92 million hectares with a total production of 4.4 million tons, of which 1.5 million tons was produced in Thailand (Jantakad, P., Kitamura, K. and Nguyen, D. C., 2016).

3.1 Land use, forestry and mining in Cambodia

Cambodia land use has been changed rapidly, especially during the last decade, in which resulted from development activities. In 2006, forest cover was estimated at 59.9% of the total land area of the country. However, this forest cover was decreased to 57.7% of the total land area of the country in 2020. While forest cover has decreasing from year to year, agricultural land has been increased. It was reported that rice production area was increased from 2.72 million hectare in 2009 to 3.05 million hectare in 2013. The same trend with rice production area, the production areas of other four main crops, namely: maize, cassava, mung bean and soya bean, were increased from 206,058 to 239,748 ha, 160,326 to 421,375 ha, 49,599 to 54,312 ha, and 96,388 to 80,680 ha from 2009 to 2013, respectively. Among four main crops, cassava seems to be a promising opportunity for case income to local community because the total land area has been increasing rapidly during the last three years.

Because of the boom of economic land concession, some forest area have been converted to industrial crop and also the forest plantation such as acacia, eucalyptus and teak plantations, as well as plantation. The area for rubber plantation has been increased from 129,920 ha in 2009 to 328,771 ha in 2013. According to MAFF, till 2012, the Royal Government of Cambodia has granted Economic Land Concession to 118 companies with the total land area of 1,204,750 ha. Among these companies, 39 companies was recorded to plant forest tree species.

Total cultivated area of Cambodia is about 4.37million ha (24% of the land), while forests cover about 56%. Rice is the dominant crop, which covers approximately 3.57millionha, (80% of agricultural land) including the area of receding, floating rice and paddy rice interspersed with villages. Figure 3 shows land use and land cover in Cambodia.

The result of geological studies and mineral investigations, carried out since the latter half of 19th century by French and Chinese geologists, have indicated significant mineral potential in Cambodia, including gold, iron, bauxite, manganese, silica, kaolin, limestone, phosphate, rubies, coal, construction materials and other minerals. But, the reserves of those mineral resources have not been evaluated yet for development and mining.

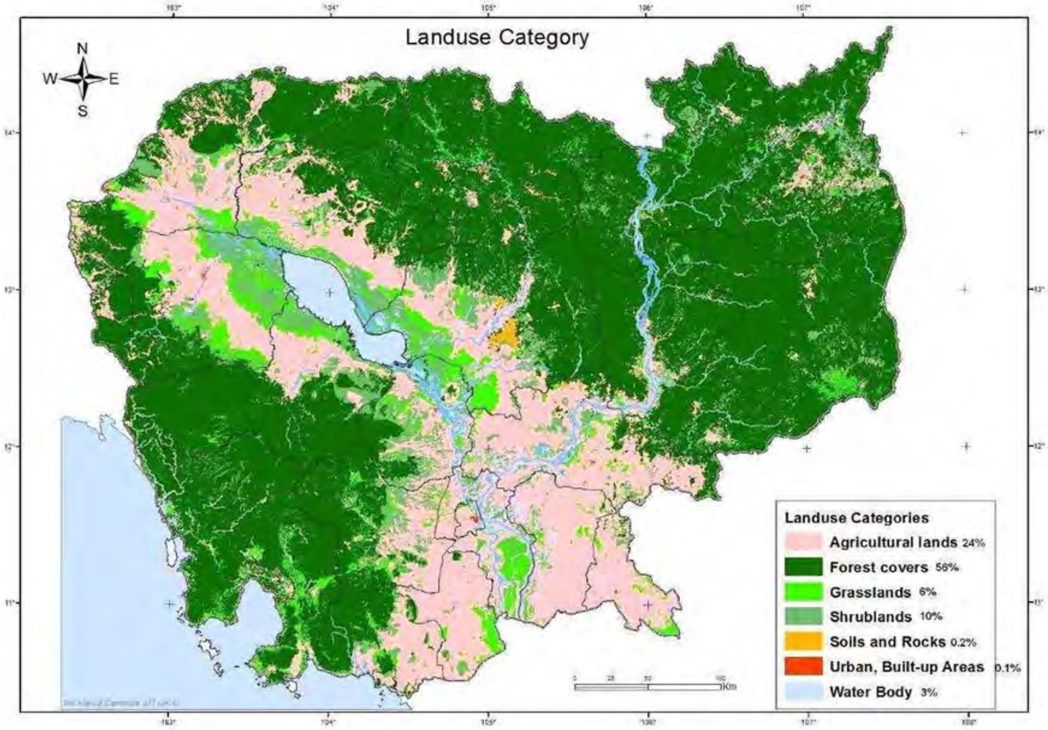


Figure 3: Land use and land cover in Cambodia

In summary, the following table shows the current area of agriculture and land use in 2007.

Table 2: 2007 agriculture, forest and surface mining areas in Cambodia

Cambodia	2007
Rainfed agriculture (ha)	82,059
Forest (ha)	462,769
Surface mining (ha)	47,977

3.1.1 Rainfed agriculture

In addition to forest tree plantation development by ELC, cassava is industrial and upland crop which is popular by local community, especially local people in the provinces neighboring to Vietnam and Thailand such as Kampong Cham, Battambang, Svay Rieng, Kratie, Pailin, Banteay Meanchey. The cultivated land for cassava production has increased from year to year.

Cassava is the upland crop that has gained greatest in popularity, reflecting a combination of a high demand for domestic use and for export, and relatively high prices. The total area of four main crops (maize, cassava, mung bean, and soya) was increased from 392,755 ha in 2007 to 796,123 ha in 2013, which is double. The greatest increase has been in Kampong Cham province in Northeast Cambodia.

Cassava is adaptable to diverse climates and can be grown in soil with low fertility. It is planted either as a single crop or intercropped with maize, legumes, vegetables, rubber or other plants. Cassava is normally planted during February-April and harvested in eight of 12 months depending on market price and the availability of labor for harvesting.

Cassava is annual crop. The cassava planting materials are kept by farmers from one planting season to another. However, the farmers have limited access to healthy/good quality planting materials. In the last few years, the planting materials were often infected with diseases/pests. The farmers do not know the names of cassava varieties that they are planting. However, they noticed that these varieties are imported from Vietnam, Thailand, Malaysia, etc. This indicates that the selection of good varieties is very limited, because different varieties are used for mixed planting.

The investment cost of cassava production involve with land rental, land operation, cost of inputs, labor, loan, and others. The total production cost of cassava per hectare was estimated at USD329. The largest share of cassava production cost is land which is accounted to 40% of the total cost or USD 132 per hectare. This followed by labor cost accounted to 34.5% of the total cost. Even the total cost is USD 329 per hectare, the input from family shared 62% while the purchasing input shared only 38% of the total production cost of cassava.

The average production of cassava per hectare in Momet in 2010-2011 was 20t/ha. The price of cassava fluctuates depending on market demand, especially demand from neighboring countries such as Vietnam. In 2003, the price of fresh cassava ranged from 290 to 310 riels/kg (about USD 0.075). The farmers prefer to sell fresh rather than dry cassava; furthermore, selling fresh cassava is easier for local community so that they can get money sooner for paying back the production cost. In addition, it is lower risk than selling dry cassava. To make dry cassava, the farmers need more labor and time, and the price is not really good enough to attract them.

It should be noted that the production cost of Cassava in Battambang province is higher than in Kampong Cham province. The discussion with farmer in December in 2015 on the production cost of cassava was reported USD440/ha while in Kampong Cham was only USD329/ha. However, the production and, thus, more family inputs than production in Battambang province. Furthermore, the average yield of cassava in Battambang was estimated at 30 t/ha while in Kampong Cham was only around 20 t/ha.

Cambodian farmers mostly export fresh cassava, while there are very limited processing plants inside the country. Fresh cassava is mainly exported to Vietnam and dry cassava chips are exported to both Thailand and Vietnam: cassava farmers along the Cambodia-Thai border make the dry chips. The price of cassava fluctuates depending on market demand in the neighboring countries.

Aside from cassava, maize is the second popular crop for local community and Investment Company. According to MAFF, the area for maize production was increased from 216,330 ha in 2012 to 239,748 ha in 2013. It was reported during the discussion that the average yield of maize in Ratatanak Mondul district of Battambang province was at 4 t/ha. The current price of this product was KHR810,000/t (around USD203/t).

3.1.2 Forestry

For contribution to economic development, the Royal Government of Cambodia has allocated some degraded forest areas for economic land concession (ELC). These ELC planted different crop and tree such as rubber plantation, forest plantation, and industrial crop. The major goal of this ELC is to provide free (non-use) land for agricultural and agro-industrial plantation, and processing for export, which is expected by the government to create the jobs and generate income for the people living in the rural area.

Some ELCs has planted forest tree species such as Tectona grandis, Acacia sp, Eucarlyptus sp and pine. Among 40 ELCs which is accounted to 46% of the total ELCs involve with forest tree plantation establishment, there are 26 companies reported planting acacia while 14 companies reported planting Teak (Tectona grandis).

The cost of acacia plantation consists of seed, land preparation, labor for planting, maintenance, post/pole, farm tools, chemical and fertilizer, and gasoline. It is reported that an average cost of acacia plantation was about USD 256 per ha for the period of 5 years with the maximum of USD 1078 per ha in the first year and minimum of USD 25 per ha in the fifth year.

It is reported the results of meeting with company in Kampong Thom that the price of 5 year old acacia plantation was ranging from USD 1,500 to 2,700 per ha. This result was confirmed with the discussion with key informant in Stoeung Treng province.

The cost of teak plantation consisted mainly of seeding, land preparation, planting, plantation maintenance, and staff salary. The cost of teak plantation is obtained from the key informant who works at the private company which has been awarded economic land concession of 5,000 ha by the government. Therefore, the cost of land rental which commonly included in the cost estimation of some other study is excluded in this study.

The harvesting cycle of teak plantation is 12 years which is two time longer than harvesting cycle of some forest tree species such as acacia and eucalyptus. An average cost of teak plantation is USD 1,102 per ha for the period of 12 years with the maximum of USD 2,557 in the first year, and the minimum of USD 800 per ha from the fourth year on ward. The largest share of teak plantation is personnel cost – representing 63% of total expenditure in the first year, followed by 92% in the second year, and 100% in the fourth year onward.

Teak has a very small proportion of world timber production and trade. The estimated market share of teak logs in total tropical round wood production is less than 2 % but in terms of value it is much larger since teak is part of the high-value hardwood market. Planted teak forests have globally attracted large investments from the private sector in many countries.

Between 2005 and 2014, the global annual trade of teak roundwood was more than 1 million m^3 on average; the imports were valued at US$487 million a year, which is about 3 percent of the value of the global timber trade (US$15.5 million). In Cambodia, however, teak logs are extremely small compared with acacia and eucalyptus – registered only 20 Sdt in 2009 anad 6 Sdt in 2011.

To date, the teak planters have never experience in selling teak products to the market due to plantation establishment is still in the initial stage. Therefore, the price of teak from teak plantation establishment seems to be unknown. However, it is reported that the price of teak round logs from plantations published by the World Trade Price in 2012 was 500 USD per m^3 and the production of 250 m^3 per hectare, the value of teak at year 12 in one hectare is estimated at 125,000 USD (Menrith, 2015).

3.1.3 Mining

The rest of geological studies and mineral investigations, carried out since the latter half of 19th century by French and Chinese geologists, have indicated significant mineral potential in Cambodia, including gold, iron, bauxite, manganese, silica sand, kaolin, limestone, phosphate, sapphires, rubies, coal, construction materials and other minerals.

By using the available mineral and geological data, so far there are around 91 companies (from Australia, China, Vietnam, Thailand, and domestic) licensed to conduct 139 exploration projects. Currently, they are being under their exploration phase. The exploration license includes metallic mineral, bauxite, antimony, chrome, coal, silica, sand, and white clay.

It is reported that there are currently 19 gold deposits in Cambodia, according to the Strategic Plan on the Management of Mercury and Mercury Containing Waste in Artisanal Small Scale Gold Mining. Gold mining in Cambodia is currently shifting from small-scale community-level activity to become increasingly mechanized, industrial-scale activity undertaken by local, national and international stakeholders. The peak of the mining season (that is, during the dry season from November to May the following year), between 5,000 and 6,000 people worked as artisanal miners.

3.2 Land use, forestry and mining in Lao PDR

The land classification in Laos has divided in 3 main types such as: 1) forest (forest cover, forest defines for protect water resources, the area for forest restoration and the area for plantation forest), 2) agriculture (current paddy field, areas for paddy field expansion, area for crop long and short cycle, pasture and other agriculture land, and 3) other land (Mienmany, 2016).

In 2008 the forest area of Laos had 70.24% or 16,632,376 hectare and the country expects that in 2020 the forest area will be slightly increase 1.59% (71.83%) or 17,009,845 hectare by increasing the area of plantation forest and the restoration forest up to 12% while the forest cover will be slightly decrease from 40.92% to be 40.34%. This is based on the policy of the Lao government strategy that trying to increase the forest area to be 70% by 2020. On the other hand, the agriculture land in 2008 had 19% or 4,728,966 hectare with total current used area approximately 2 million hectare or around 9.5% of the country area and this agriculture will increase to 21% in 2020 by increase 1 million hectare for rice expansion and 831,138 hectare and 899,262 hectare for the crop long cycle and short cycle respectively. The area for rice expansion is to support the target of rice production to be 5 million to in 2020 for the food security as well as the export to other country. In addition, the other land which includes the residential area, water resources, wet land, stone area and etc will be decreased from 10% in 2008 to be 7% of the country area in 2020.

In summary, the following table shows the current area of agriculture and land use in 2007 in Lao PDR.

Table 3: 2007 agriculture, forest and surface mining areas in Lao PDR

Lao PDR	2007
Rainfed agriculture (ha)	861,920
Forest (ha)	9,552,425
Surface mining (ha)	323,114

Rural development in the uplands of Lao PDR has presented many challenges for farmers and their communities. GoL's policy is directed at reducing the production of upland rice and providing sustainable alternative livelihoods for upland farmers.

As we known that slash and burn agriculture in Lao PDR is practiced widely in upland, rural areas, and it is significant to the cultures of ethnic groups. It can be sustained with long fallow periods and when population densities are low. But productivity is extremely low, and it is vulnerable to both drought and excessive rain. When pressures on land and forest increase, fallow periods are shortened, resulting in increased degradation and deforestation. The clearance of forest for shifting cultivation is declining, but still amounts to an estimated 200,000 ha per year.

In general, reasons of impact agricultural productivity, particularly in valley and uplands areas, they are caused by:

- Small landholders, with about half of farm households owing less than 1 ha;
- In-secure land tenure;
- Heavy dependency on rainfall in the wet season, with little possibility of dry season cultivation;
- Natural disasters, including floods and landslides;
- High cost of quality inputs such as fertilizers, seed, tools and machinery;
- Poor agro-processing and storage to reduce post-harvest losses;
- Inadequate markets and transport infrastructure and services that make it difficult to shift surplus food from have to have not provinces and district;
- Unexpected ordinance (UXOs), especially along the border with Vietnam, which it impact an agricultural land and reduce cultivation;
- Reduce available land for cultivation;
- Lack of technical agricultural training into farmers (insufficient farmer education) at provincial and district levels;
- Insufficient an infrastructure for agricultural system for example new roads assess to be a carry out agricultural land/product;
- Internal and external labor migration is high and it not enough lab for maintain the agricultural activities. Most external migrants work in Thailand, which was home to an estimated more than 150,000 of Lao workers which were registered and un-registered in 2014;
- Lack early warning system for agricultural when disasters is coming or standard operating procedures for who will do what during the immediate onset of disasters. And this is hampered by the lack of a legal framework Governing Emergency Relief operations. But later on Lao PDR had National Disaster committee and it could solve a flood prevention in 2008.

3.2.1 Rainfed Agriculture

Rainfed agriculture refers to those agricultural systems that are not irrigated and rely solely on rainfall for their water supply. About 80% of the world's farmed lands are rainfed and this ratio rises up to 88% in mainland Southeast Asia so "Tropical uplands" of northern and central in Lao PDR were main crops grown on rainfed lands in Lao PDR include maize, sweet corn, soybean, sugarcane, tobacco, coffee, upland rice and a range of fruits and vegetables.

Vegetables are mostly grown in the dry season (October-May) while rice is mostly grown during the rainy season (June-September).

These systems are highly sensitive to climate variability, which limits agricultural production. Often, the total amount of rainfall is more than adequate for crop growth, but the variation between years and distribution within the wet season means that unpredictable droughts and water shortages reduce production. Inundation can reduce productivity or even completely destroy crops.

Irrigated rice is also grown during the dry season. Upland rice planted area is baseline 2007 and comparison with 2014.

In this year 2007 characteristics of southern Lao PDR for crop plantation such as for Saravane province was planted area of coffee 20,935 ha and Champasack province was 32,780 ha. But, northern Lao PDR like Luanprabang province was a plantation the area of Job's tear 7,350 and Sesam with 8,440 ha.

In the year 2014 characteristic of southern Lao PDR for crop plantation such as for Champasak province was the area for coffee plantation was increased 49,000 ha also Saravan province with 23,910 ha, Sekong with 11,425 ha and Savannakhet province was increased the area plantation of sugarcane with 14,565 ha.

About shifting agriculture, it is a negative trend highlighted in Lao PDR's Agriculture Development Strategy 2011-2020. Encroachment on forest areas as a result of land concessions and increasing exploitation of the agricultural and natural resource sector raises major social and environmental concerns. The government has requested FAO assistance to apply Participatory Negotiated Territorial Development (PNTD) to address these issues with a multi-stakeholder, gender sensitive and negotiated land use and resource development approach.

3.2.2 Forestry

The Forestry Strategy 2020 recognizes that forests have an important role in local livelihood systems. In the upland areas the strategy aims at, for example, linking rehabilitation, conservation and the expansion of forest cover with meeting the needs for food and commodity production. It also aims at decreasing the amount of land used for shifting cultivation. The implementation principles of the strategy include the development of village based natural resources management and the promotion of sustainable participatory Non-timber forest product (NTFP) management and processing. The strategy targets to complete the land-forest allocation programme by 2020.

The GoL has set an ambitious goal of reaching 65% forest cover by 2015 and 70% by 2020. The Forestry Law defines and delineates three forest management categories: conservation, protection and production forest. These categories do not indicate the current land cover but are instead administrative categories determining management and land use regulations. By overlapping the inventory data with spatial data, almost one third of all concessions and leases granted were shown to occur on lands categorized as forest. While production forest could be expected to host the greatest number of investment projects considering limitations on development activities in protection and conservation forest areas, most investment occurs on lands categorized as protection forest.

The statistics is based on visual point sampling and maps are produces to visualize major changes areas. The production of forest cover is 40.25% in 2009. The potential forest and current forest categories are relatively difficult to separate from the imageries, thus, there are not very clear changes in national level. Country level standard error of sampling is 0.38, which means that with 95% confidence the results are between 39.5-41.0%. The region specific results indicate regional changes. Fairly rapid decrease in Southern (-1.1%/year) and Central (-0.4%/year) regions can be identified. Clear development in Southern region needs special attention. Proportion of potential forest has increased and part of forest areas has been converted into other land use category. Significant reduction of forest area can be identified in Bolikhamxay, Khammouane in central region. Similar minor trend can be found in Savannakhet. The largest reduction in forest area can be found in Salavan, Xekong, and Champassak provinces (13-16% in each).

3.3 Land use, forestry and mining in Thailand

The study area covered eight provinces including Chiang Rai, Loei Khai, Bueng Kan, Nakhon Phanom, Mukdahan, Amnat Charoen, and Ubon Ratchathanai provinces (TNMC, 2016).

Total MRC province area in 2007 was approximately 5.82 million hectares. Agricultural area occupied 56.3 percent of total area where paddy field was approximately 2.01 million hectare. Field crop and perennial areas covered 0.69 and 0.27 million hectares respectively. Dense forest and disturbed forest areas covered 1.45 and 0.46 million hectares respectively. Other area (e.g., urban, built-up land and water body) occupies about 10.8 percent of total area.

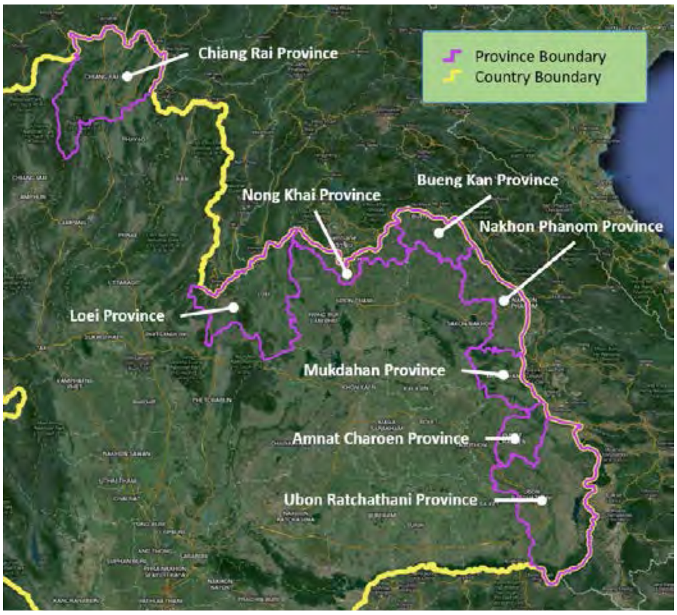


Figure 4: Boundaries of the eight provincial areas used in the study (Google Maps)

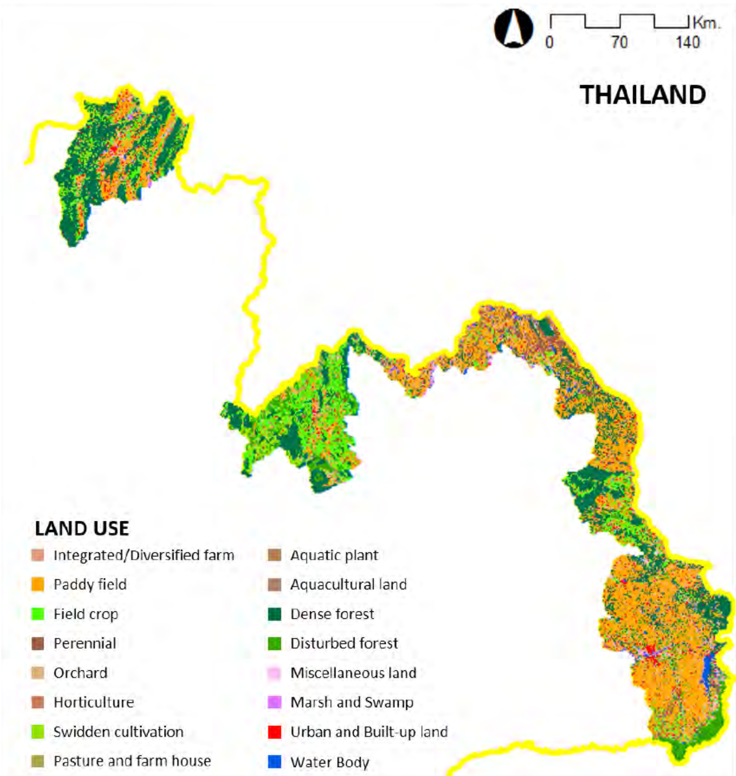


Figure 5: Land use of the eight provincial areas used in the study

The areas for each type of land use is shown in below table:

Table 4: Land use in the Thai provincial study areas

Land use type	Area [ha]	Percent
Agriculture	3,279,182	56.3
Integrated farm /Diversified farm	1,286	0.0
Paddy field	2,015,302	61.5
Field crop	696,382	21.2
Perennial	278,217	8.5
Orchard	160,998	4.9
Horticulture	3,914	0.1
Swidden cultivation	110,557	3.4
Pasture and farm house	5,659	0.2
Aquatic plant	21	0.0
Aquacultural land	6,846	0.2
Forest	1,914,286	32.9
Dense forest	1,453,534	75.9
Disturbed forest	460,752	24.1
Other	628,339	10.8
Miscellaneous land	203,350	32.4
Marsh and Swamp	36,160	5.8
Urban and Built-up land	187,071	29.8
Water Body	147,062	23.4
Unclassified	54,696	8.7
Total	**5,821,807**	**100.0**

In summary, the following table shows the current area of agriculture and land use in 2007.

Table 5: Summary of the land use in the Thai provincial study areas

Rainfed agriculture (ha)	3,279,182
Forest (ha)	1,914,286
Surface mining (ha)	1,214

3.3.1 Rainfed Agriculture

Crop suitability map is a key spatial feature that used to simulate a future land use in this study. Rice is a target crop of conversion. Unsuitable paddy field will be convert to other better choice of agricultural activity as in agricultural management zoning policy or forest area as in forest restoration policy.

A total area of Thailand MRC province is 5.82 million hectare approximately, there are around 0.94 million hectares classified by LDD as suitable paddy field where 2.76 million hectares are unsuitable. Chiang Rai (CR) province is only one province that has suitable paddy field more than fifty percent of provincial total area. Agricultural management zoning policy may impact to Loei (LO), Amnat Charoen (AM) and Ubon Rathcathani (UB) provinces the most. More than eighty percent of area will convert to other better choice. In total, 2.10 million hectare are un classified and carries uncertainty for this study.

Maize is one of alternative crops of paddy field conversion. However, the opportunity may be high only Mukdahan (MU) province where the suitable area is higher than forty percent Loei (LO) seems to be a second choice for maize that will be replace on unsuitable paddy field. Bueng Kan (BK), Amnat Charoen (AM) and Ubon Ratchathanai (UB) have the most less area of suitable area for maize compare to the other provinces. The chance of conversion depends on numbers of point that spatially meet the condition of conversion.

Sugarcane is the one of preferable crop for the Thai northern farmers because of the high market opportunity. Serval sugar mills can be found in this region, however there is no spatial data can be provided to this study. Conversion of unsuitable paddy field to sugarcane used to be a small pilot project of agricultural management zoning policy. If sugar industrial gets involve in the policy implementation, this might be a turning point for farmers in this region to convert their unsuitable paddy field to sugarcane field in the future. Mukdahan (MU) and Loei (LO) provinces have a high chance of conversion because of the high percentage of suitable area for growing sugarcane. Bueng Kan (BK), Nakorn Panom (NP) and Nong Khai (NK) have the lower chance of conversion.

Cassava is the one that Thai government tries to promote for farmers. Cassava can be both food crop and energy crop. However, price is a key factor that limits the expansion of cassava in Thailand. In addition, suitable area for growing is limited. Within the MRC provinces, Mukdahan (MU) and Loei (LO) have the highest opportunity to convert unsuitable paddy field to cassava, while Bueng Kan (BK) and Chiang Rai (CR) provinces have the lowest oppprtunity due to the less area of suitable land.

3.3.2 Forestry

Thailand Land Development Department (LDD) provided land use maps of eight provinces of Thailand. The spatial information was collected during 2006 and 2007. GIS was used to be summarized land use areas for those maps.

Bueng Kan (BK), Nong Khai (NK) and Amnat Charoen (AM) provinces area occupied by agricultural area around 75.0, 67.6 and 63.2 percent of each province’s total area where Mukdahan (MU) and Chiang Rai (CR) provinces have only 47.8 and 42.5 percent of agricultural area. Paddy field is a key land use type of almost all provinces except Loei (LO) province where field crop occupies 0.31 million hectares. Swidden cultivation can be found in Chiang Rai and Loei provinces.

Mukdahan and Chiang Rai pronvinces have 48.8 and 46.6 percent of area occupied by forest area. Forest areas of Bueng Kan and Nong Khai provinces are around 8.0 and 14.2 percent of pronvincial total area, respectively. Dense forest is the main forest type of all provinces except Ubon Rathctani.

Rubber is only one perennial crop that Thai government promotes for both economic and environment issues. Rubber product mainly is latex. Today, global latex price has dropped during few years, hence conversion from unsuitable paddy field to rubber is under considering of policy makers. However, rubber tree can be a source of wood product for furniture industry. Rubber also plays a role of perennial tree in forest even it has less biodiversity in rubber plantation area. For this reason, rubber may still be a good alternative crop for farmers. Chiang Rai (CR), Mukdahan (MU) and Loei (LO) provinces have a high opportunity to expand rubber plantation on unsuitable paddy field with the large area of suitable land compare to the other provinces of this study while the suitable lands of Amnat Charoen (AM), Ubon Rathcathani (UB), Nakorn Panom (NP) and Bueng Kan (BK) provinces are less than 10 percent of provincial area.

Protected forest area is a key limitation of agricultural expansion due to the forest restoration policy. Chiang Rai (CR), Loei (LO), Mukdahan (MU) and Bueng Kan (BK) provinces have protected forest area around 65.0, 64.9, 62.1 and 55.9 percent, respectively, while Nakorn Panom (NP) province has only 16.8 percent of protected forest area. This can be expected that the first four provinces might have less opportunity to expand agricultural production in the future.

3.3.3 Mining

In the past, mining industry in Thailand was one of the key industries as it was important for producing and feeding raw materials for the industry sector, especially ore and subsequent products from mineral refinement and metal work. They were used as the raw materials for making products and goods in the subsequent industries, which were important for the country, for example, construction industry, iron industry, gem and accessory industry, glass and mirror industry, and ceramic industry, etc. Some minerals were also used in alternative-energy sector, for example, the coal was used, instead of other minerals, to produce electricity. This led to economic growth of the country.

3.4 Land use, forestry and mining in Viet Nam

Vietnam is characterized by two typical systems according to the area.
In the Mekong Delta, intensive irrigation of rice crops is conducted. The natural and engineered network of canals feeds the paddy rice plots either by gravity or by pumping according to the tide water level. In the current situation, 1.9 million ha are fully developed. Three seasons of rice production are occurring in the delta area.
Irrigation systems in the Central Highlands (Upper Se San and Srepok Basins) of Viet Nam are typical reservoir-gravity canal systems. The irrigation designed capacity is 165,086 ha but the actual irrigated area totals 124,191 ha or equal to 75.2% of the design capacity

Figure 6 and Figure 7 show land use maps 2010 in Mekong Delta and Central Highlands.

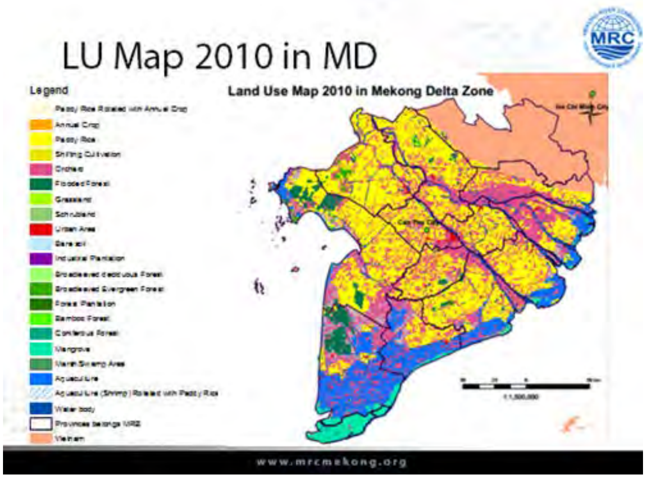


Figure 6: Mekong Delta land use (MRC land cover 2010)

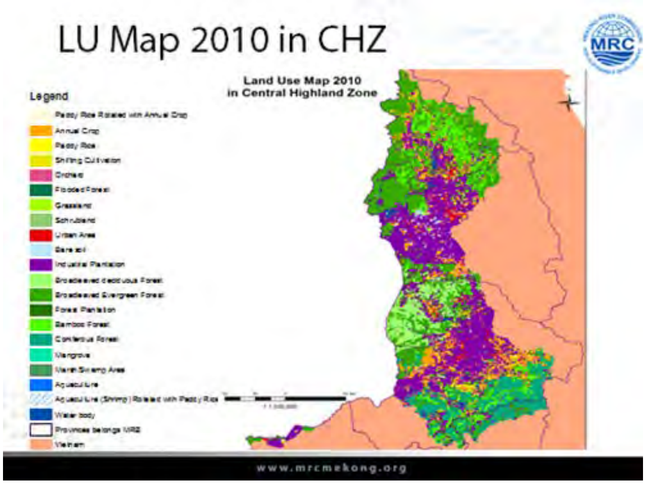


Figure 7: Central highlands land use (MRC land cover 2010)

Central Highlands consists of mountain ranges with height of about 2000m and the plateau with elevations ranging from 300-800 m sloping to the west, southwest and south. Mountainous area with an altitude of over 800 meters, with an area of about 1,536 hectare, accounts for 34.5% of the whole area. The total natural area of the Central Highlands in 2008 was 5,464 thousand hectares, including quite large area for agriculture. Agricultural land accounts for 29.8%, forest land area accounts for 57.1% of nature of the region.

Mekong Delta region of Vietnam displays a variety of physical landscapes, but is dominated by flat flood plains in the south, with a few hills in the north and west. This diversity of terrain was largely the product of tectonic uplift and folding brought about by the collision of the Indian and Eurasian tectonic plates about 50 million years ago. The soil of the lower Delta consists mainly of sediment from the Mekong and its tributaries, deposited over thousands of years as the river changed its course due to the flatness of the low-lying terrain.

Regarding mining, the mineral kind and capacity in Central Highlands and in Mekong Delta are as follows:
In Central Highlands: The mineral is mined primarily focused on non-metallic minerals (most common building materials such as building stones, sand, gravel, clay) and industrial minerals as kaolin, diatomite, bentonite, pozzolanic; With the exception of bauxite are in the pilot process, the mining area in Lam Dong, a several iron mines in Gia Lai and Dak Lak, two mines of lead – zinc; The active mines are on a small scale by local licensing and local businesses are the main operators. The mineral mine mainly uses simple technology, the mining activities are mainly self-organized and focus on ore mining and crafts;
In Mekong Delta: Mekong delta has poor mineral resources both in capacity and mineral kinds; the most exploited mineral kind is sand, which causes a concern environmental impact. Other kinds of minerals are mainly ones for construction materials production (Nguyen, 2016).

In summary, the following table shows the current area of agriculture and land use in 2007.

Table 6: Summary of the land use in Vietnam

Rainfed agriculture (ha)	322,556
Forest (ha)	2,868,708
Surface mining (ha)	132,080

4 Estimated current sector economic values

Based on the farm gate price of rice and maize in respective LMB countries, the total economic value (US$/annum) of rainfed rice and maize in 2013 was estimated at US$ 6,111 million with rice accounting for US$ 5,5504 million and maize contributing a further US$ 607 million.

Table 7: Economic value of rain fed rice and maize in 2013

	Rice				Maize				Total
	Rainfed harvest area (Ha)	Rainfed production (ton)	Farm gate price (US$/ton)	Economic value (US$/annum)	Rainfed harvest area (Ha)*	Rainfed production (ton)*	Farm gate price (US$/ton)**	Economic value (US$/ annum)	Economic value (US$/annum)
Cambodia	2,062,004	6,030,854	268	1,613,657,301	189,121	824,553	138	113,788,578	1,727,445,879
Lao PDR	657,488	2,616,504	248	648,912,422	174,167	1,008,044	138	139,110,252	788,022,673
Thailand	5,640,349	13,298,185	244	3,241,785,806	364,881	1,544,398	138	213,127,334	3,454,913,140
Viet Nam	-	-		-	191,234	1,020,834	138	140,875,284	140,875,284
Total	**8,359,841**	**21,945,543**		**5,504,355,529**	**919,404**	**4,397,829**		**606,901,447**	**6,111,256,976**

4.1 Estimated current economic value of agriculture and forestry sectors in Cambodia

Given the cash flow of each crop production and forest tree species plantation that got from literature review, local community consultation, and the assumption of the discount rate; the Net Present Value for rainfed agriculture (cassava and maize) and forestry (acacia and teak) can be written as following:

$$\text{NPV}= \sum_{t=1}^{n} \frac{(Bt-Ct)}{(1+i)^t}$$

Where:

Bt and Ct - benefit and cost during period t, respectively

n - Number of time periods of the project

i - Discount rate

Benefit cost ratio (B/C) is the discounted gross benefit divided by the discounted gross cost. The B/C measures the social equity and economic efficiency or resources utilization from the stand point of the society. A decision of B/C is to accept projects with a ratio above one. B/C has the following formula:

$$B/C = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+i)^t}}$$

Bt, Ct, I, and t as defined for NPV

(1) Rainfed agriculture

The NPV of cassava is the highest amongst compared with maize. It registered at USD 1,084 per ha if the discount rate was only 8% and USD 1,007 per half if the discount rate was 15%. With the discount rate of 10%, the NPV of cassava was 15 times higher than that of maize – indicating that cassava is the most profitable crop. Furthermore, the investment cost of cassava is even lower than maize.

Table 8: Net present value and benefit cost ratio of cassava and maize

Tree species	NPV			B/C		
	8%	10%	15%	8%	10%	15%
Cassava	1,084	1,064	1,007	4.6	4.6	4.4
Maize	208	204	195	1.4	1.4	1.4

(2) Forestry

The NPV of acacia was negative with the minimum price (USD 1500/ha). However, the NPV of acacia turns to positive if the maximum price (USD 2700/ha) is applied. The benefit cost ratio ranges from 1.1 to 1.4. The NPV for teak is the highest amongst the selected species. It registered at USD 43,675 per ha if the discount rate was only 8% and USD 18,604 per ha if the discount rate was 15%. With the discount rate of 10%, the NPV for teak was 90times higher than that of acacia – indicating that teak is the most profitable tree species even though its initial investment seems to be the largest and its rotation year is twice longer than acacia. Its benefit and cost ration is in the range of 5.4 to 3.3.

Table 9: Net present value and benefit cost ratio pre ha of acacia and teak plantation

Tree species	NPV			B/C		
	8%	10%	15%	8%	10%	15%
Acacia (*Acacia* spp.)	526	377	84	1.4	1.3	1.1
Teak (*Tectona grandis*)	43,675	34,436	18,604	5.4	4.7	3.3

This would suggest that investment in teak plantation may be an economic viable under some condition. However, it should be noted that the value of NPV shown above excluded rental of land value.

Even the NPV of acacia is much lower than teak, but some large-scale acacia plantations have now been established by private investors. This involves with many reasons such as the investors already have established markets outside Cambodia and they have facilities to generate the value-added products meaning that private companies can be benefit from the whole value chains while local farmers mainly get benefits from firewood and pole (RA, 2015).

4.2 Estimated current economic value of mining sector in Thailand

- Production

In 2014, Thailand produced more than 40 kinds of mineral valuing at 63,005.2 million Thai Baht (1,750.1 million USD@36 Thai Baht per USD), an increase of 5.32% from 2013. The minerals with the highest production value was limestone at 18,471 million. Thai Baht followed by lignite at 17,272, gypsum at 7,205, gold at 5,845, and zinc at 3,312 million Thai baht. The Mining Production Index (MPI) was increased 2.07% from 2013 to 2014 as the number of operating mines was increased from 547 to 557.

Among the metal ores, the highest production amounts were silver at 30.98, and gold at 4.33 million grammes, iron at 0.35 and zinc at 0.23 million tones. While for the non-metallic minerals, limestone was produced the highest amount at 164.94 million tones, followed by basalt at 14.13 and gypsum at 12.45 million tones. The only mineral produced for energy was lignite at 17.99 million tones.

- Import

Even though Thailand could produce many minerals, there are some minerals that their supplies were inadequate and some that were below standards, therefore, those were needed to be imported. In 2014, the country imported minerals worth 63,383.2 million Thai Baht (1,760.6 million USD @36 Thai Baht per USD), which was an increase of 14.28% from 2013. The mineral with the highest amount imported was bituminous coal at 28,802 million Thai Baht, followed by other coals at 17,664, tin at 2,385, talc at 1,660, and niobium and vanadium at 1,085 million Thai Baht. The energy minerals (i.e., coals of bituminous and other kinds such as anthracite, coke and lignite) were among the high amount imported at a combination of 47,952 million Thai Baht, which was 75.59% of the amount of all the imported minerals.

- Export

Thailand exported some domesticly-produced minerals due to the domestic over supply. In 2014, the country exported the minerals worth of 8,803 million Thai Baht (244.5 million USD @36 Thai Baht per USD), which was an increase of 16.84% from 2013. Some of the key exported were gypsum at 5,104, feldspar at 771, anhydrite at 630, dolomite at 471, and iron at 313 million Thai Baht, which was a decrease of 21.49% from 2013. Some key exported metal minerals were tin at 9,223, gold at 5,967, silver at 618, zinc at 199, and copper at 56 million Thai Baht. The minerals were exports in 2 forms: 1) refined minerals from imported ores such as tin and zinc, and 2) unrefined ores exported as mixed metal minerals such as gold and silver (Huy, 2015).

4.3 Development trends in Cambodia

The national rice production and the yields of Irrigated rice crops have improved in the last years thanks to better water management, seeds quality and fertility management. The National Strategy lays particular emphasis on increasing the area of irrigated land, in order to make farmers less reliant on rainfall and allow them to cultivate more crops with more certainty and predictability, resulting in higher productivity and improved livelihoods. Priority is given to the rehabilitation of the thousand of existing schemes instead of the creation of new schemes. The government mobilized irrigation funds to invest in irrigation development and for the irrigation services centers to provide capacity and management support to the FWUC (RA, 2015).

Figure 8 shows agro-ecological zones in Cambodia.

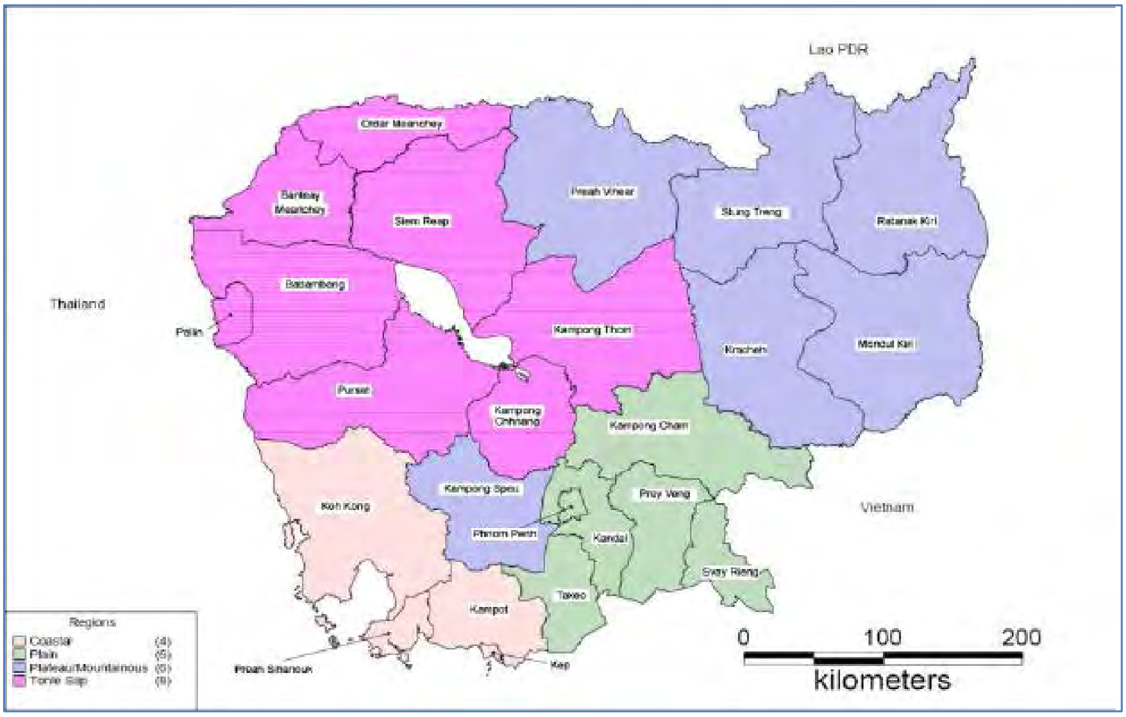


Figure 8: Agro-ecological zones in Cambodia

Figure 9 shows sub-sectors to agricultural growth in Cambodia

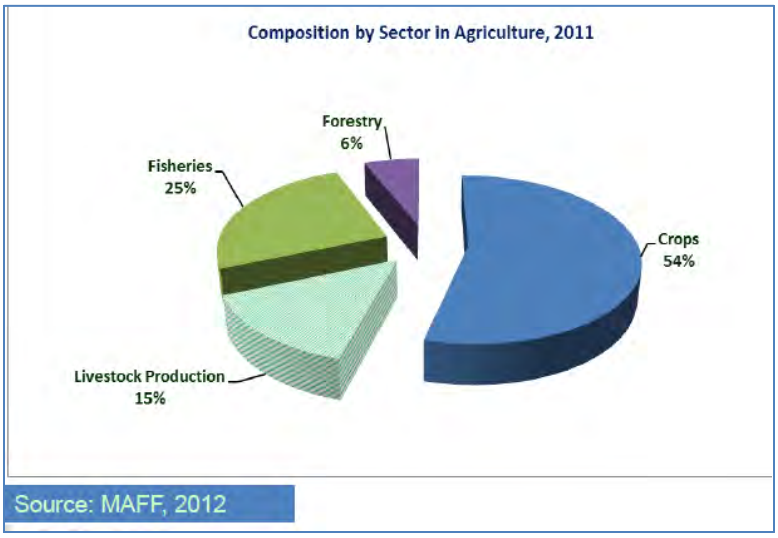


Figure 9: Sub-sectors to agricultural growth in Cambodia

Priority programmes of Agricultural Development of Cambodia are as follows:

1. Enhancing Agricultural Productivity and Diversification;
2. Increase Market Access for Agricultural Products;
3. Strengthening Institutional, Legislative Framework and Human Resource Development (HRD);
4. Sustainable Fisheries Resources Management and
5. 5. Sustainable Forestry Resource Management

It was reported by MAFF (2014) that the total production area for annual crop was increased from 392,755 ha in 2007 to 796,123 ha in 2013. Among four main annual crops, only cassava shows promising crop which covered the areas more than 50% of the total area of main crops during the last three year.

In addition to these crop, many ELC granted by MAFF have contributed to forest tree planting programme. Those forest tree species include acacia, eucalyptus, pine, and teak. The projects that were selected for this study are rain-fed agriculture, forestry (tree plantation), and mining.

Rain-fed agriculture:
Among the four-main annual crop production in Cambodia, cassava and maize cover an area of 71% of the total production area in 2009 and 2010. The area of these two crop was increased to 81% in 2011 and 2012 while in 2013 the area for these two crops continue to increase to 83% of the total land area of the four main crop production.

Forestry:
Forest tree species that were popular for tree planting by many companies are acacia and teak.

Mining:
Mining activities began during 2006-2007 when the Chinese company, Phou Yang Cambodia, obtained a license from the government to explore mines in a 4km^2 forested region in Phnom Proek from 2006-2007. However, Phou Yang obtained a license from the government for 2007-2011 to explore the area. In 2011, the company expanded to 20 hectares.

By using the available mineral and geological data, so far there are around 91 companies (from Australia, China, Vietnam, Thailand, and domestic) licensed to conduct 139 exploration. Currently, they are being under their exploration phase. However, the preliminary results showed that about 17 of 139 explorations were confirmed positive.

In summary, the following table shows area of agriculture and land use in scenario 2020 and 2040 in Cambodia.

Table 10: Cambodia land use scenarios for 2020 and 2040

Cambodia	2020		2040	
	ha	% increase from 2007	ha	% increase from 2007
Rainfed agriculture	404,500	393%	462,754	464%
Forest	462,769	0%	462,769	0%
Surface mining	47,977	0%	47,977	0%

4.4 Development trends in Lao PDR

The objective of the National Irrigation Development strategy is to create a more conducive environment for irrigated agriculture development. The strategy foresees a re-modeling and re-orienting of the mechanisms of the various areas of public management that relate to the Irrigation Agriculture Subsector. The implementation of those plans could see the new development of 101 700 Ha in the period 2015-2020 and 329 425 Ha in the period 2020-2040 reaching a total irrigated area of 446 125 Ha for the large projects. The target is to use the potential water resource by developing gravity irrigation systems in order to reduce the cost of irrigation service and production that will enhance the price competitiveness of agriculture products.

53 Large irrigation projects have been identified for development up to 2020 and 2040. According to an estimation based on designed and feasibility study, the command area the 53 projects will be able to supply irrigation water to 446,125.00 ha. The first 27 projects plan to be implemented over 101,700 Ha during 2010-2020. The remaining 26 projects will be implemented over 329,425 Ha during 2020 -2040. Figure 10 shows large irrigation projects in Lao PDR.

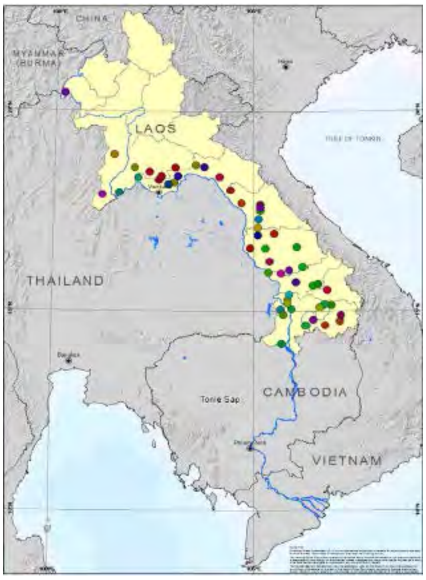


Figure 10: Large irrigation projects in Lao PDR

In 2008 the forest area of Laos had 70.24% or 16,632,376 hectare and the country expects that in 2020 the forest area will be slightly increase 1.59% (71.83%) or 17,009,845 hectare by increasing the area of plantation forest and the restoration forest up to 12% while the forest cover will be slightly decrease from 40.92% to be 40.34%. This is based on the policy of the Lao government strategy that trying to increase the forest area to be 70% by 2020.

On the other hand, the agriculture land in 2008 had 19% or 4,728,966 hectare with total current used area approximately 2 million hectare or around 9.5% of the country area and this agriculture will increase to 21% in 2020 by increase 1 million hectare for rice expansion and 831,138 hectare and 899,262 hectare for the crop long cycle and short cycle respectively. The area for rice expansion is to support the target of rice production to be 5 million ton in 2020 for the food security as well as the export to other country. In addition, the other land which includes the residential area, water resources, wet land, stone area and etc. will be decreased from 10% in 2008 to be 7% of the country area in 2020.

Based on the agriculture and forest strategy plan 2020 from Ministry of Agriculture and Forestry has classified the forest area in 4 main types: forest area, forest for protects water resources, te area for forest restoration and the area for plantation forest. The central part will have forest area more than the other part (18% of the country area) the northern part is 14% while the southern has lower than 10% of the country area. Furthermore, the northern part has more potential to increase forest cover than the other part because the forest restoration area, forest for protects water resources and area for plantation forest in the north is 33.71%, 26% is in central and 12% is in southern part. This also means that northern part had more activities causes to degraded land more than the other part.

In summary, the following table shows area of agriculture and land use in scenario 2020 and 2040 in Lao PDR.

Table 11: Lao PDR land use scenarios for 2020 and 2040

Lao PDR	2020		2040	
	ha	% increase from 2007	ha	% increase from 2007
Rainfed agriculture	1,322,724	53%	1,892,179	120%
Forest	9,552,425	0%	10,427,122	9%
Surface mining	70,629		3,279,749	

4.5 Development trends in Thailand

RID's Strategic Plan was formulated in accordance with the State Administration Plan, The Eleventh National Economic and Social Development Plan (2012-2016), and The Agricultural Development Plan. The plan can be substantially performed by applying structural measures and non-structural measures. The structural measures mainly emphasize the use of water inside the basins especially in the areas suffering from both flood and drought. The water diversion between the basins will then be considered secondly. The non-structural measures are the applications of technologies, coordination with other sectors and participations in managements of storages and irrigation. Figure 11 shows strategy to action, agricultural planning.

Figure 11: Strategy to action, agricultural planning

For Thailand, the production, import, and export of the minerals were increasing as a result of the growing economy. The domestic supplies of the minerals did not meet the demands, so the country relied on the enormous amount of the imported minerals, while at the same time, there was a decrease in the number of operating mines. The value ratio between the domestically-produced and the exported minerals was 1:2.7. only the minerals for construction that were domestically produced adequately while the other groups of the minerals having the greater import amount than domestically produced, which were for chemical and energy at the value ratios of between the domestically-produced and the exported minerals at 1:2.3 and 3.3,respectively. The demand of the minerals increased between 2010 and 2011. It was suspected to be the result of the country's economic growth, especially the government in mega projects, which was expected to increase in the future.

This study investigates trends of land use change using two major scenarios including (1) land use in 2020 and (2) land use in 2040. The land use in 2020 scenario considers all plans that is under implementation or commitment to implement and will be completed on/before 2020. In the same way, the land use in 2040 scenario considers all plans that are expected to take place before 2040 plus continued rend to develop for this study. Agricultural management zoning policy and sustainable natural resource and forest management policy are key driving force of change. The alternative crops and will be end at 2032. The natural resource and forest management policy was implement in 2014 to reach the target of 40 percent increased forest area by 2024.

In summary, the following table shows area of agriculture and land use in scenario 2020 and 2040 in Thailand.

Table 12: Thailand land use scenarios for 2020 and 2040

Thailand	2020		2040	
	ha	% increase from 2007	ha	% increase from 2007
Rainfed agriculture	3,273,538	0%	3,259,941	-1%
Forest	1,922,993	0%	1,928,797	1%
Surface mining	864	-29%	ND	

4.6 Development trends in Viet Nam

The overall objective of the Agriculture sector is to develop a comprehensive and sustainable system and to optimally utilize the potential. Generate a greater production characterized by a high productivity, quality, efficiency and competitiveness. The part of Agriculture within the *Agriculture, forest and fisheries sector* will decrease by 2020 in favor of the Aquaculture development. Irrigation development is foreseen in the Mekong Delta and Central highland areas to address the questions of the sustainable water management for land conservation (VNMC, 2015).

Development trends in Mekong Delta Area are:

- Area subject to climate change effects and urbanization growth
- The future plans only foresee a slight decrease of the irrigation development that would decrease to 2.384 million Ha in 2020 (DFS scenario) and would decrease to 2.323 million ha in 2040 (PDS scenario)
- Farmers will switch to aquaculture (shrimp) to overcome the climate change effects and seek for higher income
- Several major infrastructural projects are scheduled to meet the objectives of the water resources planning. It consists of canal works, dikes improvement, drainage water management, regulation structures and pumping stations development.

Figure 12 shows map of proposed land use to the year 2020 in Mekong Delta Area.

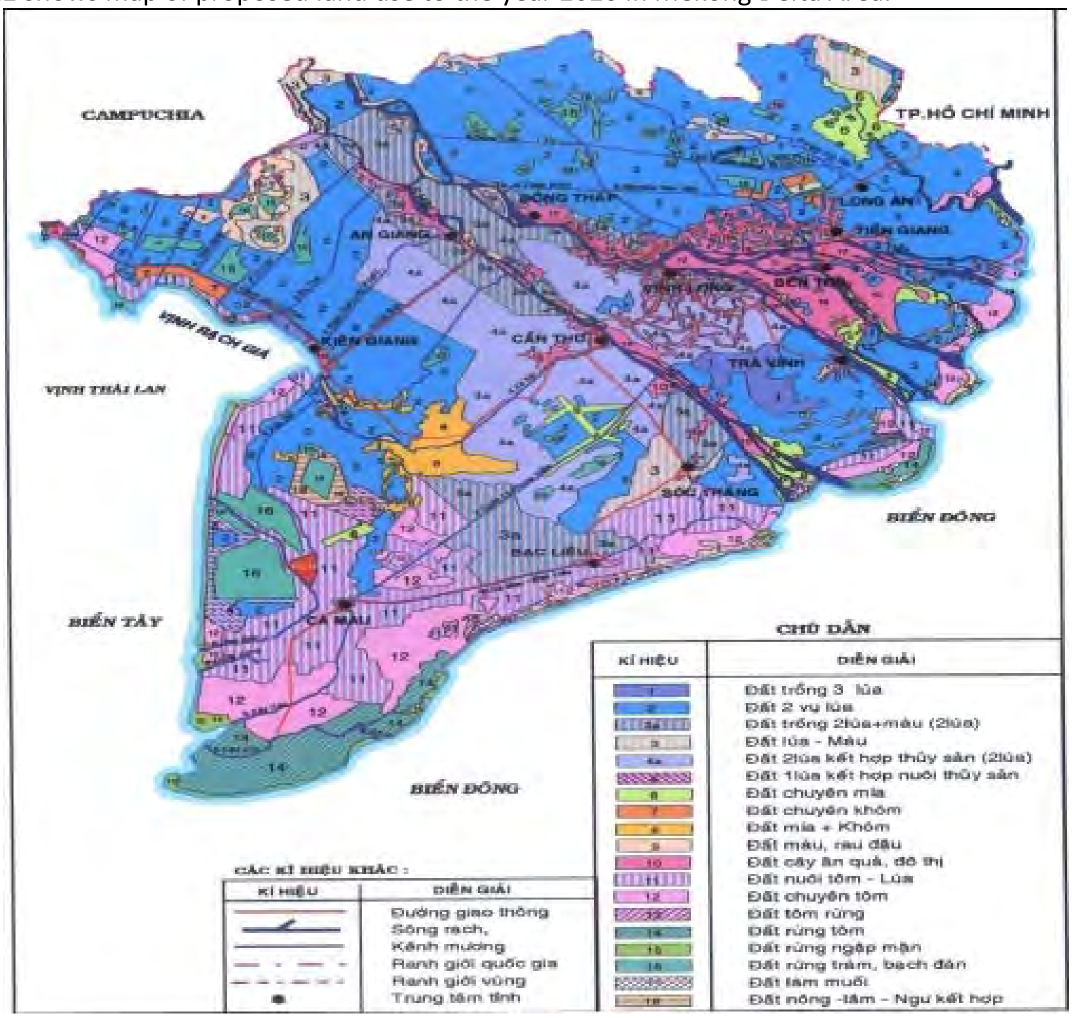


Figure 12: 2020 proposed land use for the year 2020 in the Mekong Delta

Development trends in Central Highland Area are:

- The main objective for the development of the area is to minimize the transfer of agricultural land into unsustainable land cultivation systems.
- It is foreseen to prioritize the expansion of rubber and coffee plantations and the development of land with annual crops in upland fields with irrigation.
- The development of irrigation is targeted to improve rice cultivation areas and address the transfer of water service. Irrigation development will be prioritized to the precarious areas and turn them to cropland and other crops with a high economic efficiency.

Figure 13 shows land use planning map in Central Highland Area (at province level).

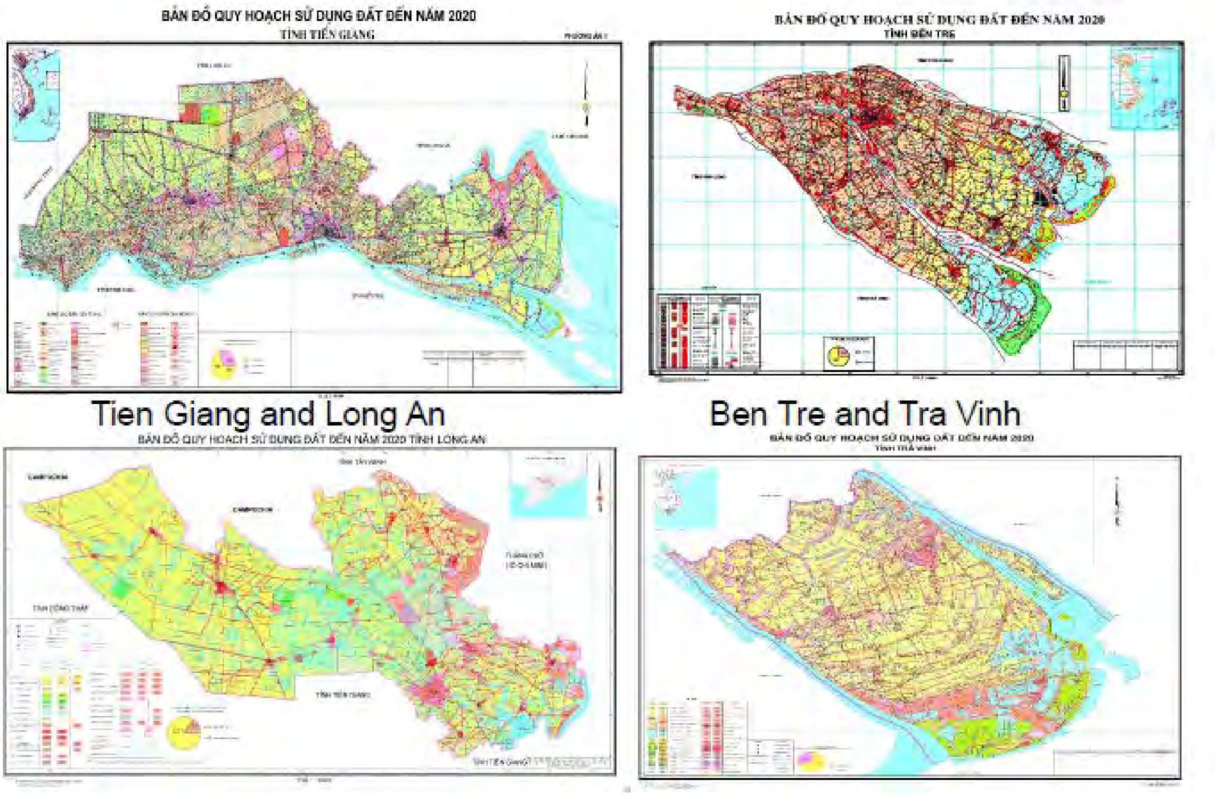


Figure 13: Provincial level land use planning map for the Central Highland Area

In summary, the following table shows area of agriculture and land use in scenario 2020 and 2040 in Vietnam.

Table 13: Vietnam land use scenarios for 2020 and 2040

Viet Nam	2020		2040	
	ha	% increase from 2007	ha	% increase from 2007
Rainfed agriculture	358,783	11%	ND	
Forest	2,733,780	-5%	2,760,271	-4%
Surface mining	175,080	33%	173,982	32%

5 Direct Impacts

Analysis of impact assessment of agriculture and land use change

Four Member Countries implemented the direct impact assessment of agriculture and land use change with slight different ways by using literature review/desk study, and/or case studies. The assessment contains social, economic, and economic aspects. In general, rain-fed agriculture, forestry, and mining may contribute to create more employment opportunity and increase income for rural people. They might improve their livelihood. The environmental impacts may include negative aspects with soil erosion, loss of soil fertility, loss of biodiversity etc. However, due to the lack of collected dataset, this analysis of impact assessment is insufficient. Further data collection and impact analysis will be required.

5.1 Direct impacts in Cambodia

(1) Rain-fed agriculture

Cassava:
Traditionally cassava production in Cambodia was only a farmstead crop production that is given mainly on the farmer backyard. However, because of high market demand, production of this crop increase rapidly, especially in Kampong Cham where the production of cassava was ranked number one in 2011 with production of 1,318,109 metric tones accounted to 31% of cassava production in Cambodia.

Maize:
For the case of HLH agriculture, significant number of jobs were created when the project began operations in 2007, providing average daily wages of KHR10,000-12,000 (USD2.5-3). However, the number of workers employed has declined considerably as the company has replaced manual labour with imported machines, for example for sowing and harvesting. This has limited villagers' opportunity to access this new income source. It is quite similar with some other cases of ELC, the land conflict and utilize of natural asset have been reported. HLH agriculture has claimed around 40 percent of villagers' paddy rice fields and cleared forest land, severely affecting local people's main and traditional sources of income, namely rice growing and charcoal production.

(2) Forestry

Acacia:
Conflict has been reported like some other companies. This conflict caused by weak communication between villagers, companies and authorities. In some cases, villagers were shocked to see the companies turn up to clear land close to their backyards. Furthermore, dispute has been occurred between the local community and company. This dispute caused by land grabbing and restriction of access to forest resources in which local community traditionally practiced for many years. The arrival of the company provides jobs opportunity to local community. However, it was reported that villagers no longer favor working for the company because its restriction and its land grabbing activities. In addition, the company built the access road to the company site. This road is not only for company transportation, but also for local community to some extent.

Teak:
In O Tanoeung village, most villagers are farmers who always consider paddy rice cultivation as a main activity followed by animal raising, NTFP collection, hunting and fishing for their living. Their rice fields were taken from the forest then passed through from one generation to another. The farmlands have traditionally been recognized by use. However, their rice field has been encroached by Global agricultural development company. The company also limited local community's access to natural resources that was claimed by the company. Therefore, like previous company, land dispute has been recorded. In O

Tanoeung villagers ignore and reject participation in such a development process even though it has intended to include the local people through creating jobs for them (RA, 2015).

(3) Mining:

Mining generates some employment opportunities. However, the benefits will not be long term. Despite mining company helps local people earn for their living, this income is never sufficient enough to shun them from living from hand to mouth. Mining also has not resulted in infrastructure improvements. Besides hiring local people to work, no any infrastructure such as road, school or health center have been built.

5.2 Direct impacts in Lao PDR

The assessment of direct impacts of development was implemented with a case study of a sugarcane development project (Phongpachith, 2015).

The case study of the sugarcane development project shows as follows: (1) the most significant economic impact is that the plantation creates employment and income generation activities for local people. (2) the social impacts is that the project has had impacts on traditional livelihoods from independent farmers to dependent employees on an industrial plantation. (3) the environmental impact is that the plantation have had negative health effects for workers mainly attributed to contamination and use of chemical materials, especially pesticides.

According the socio-economic status, resources and livelihoods of the case study population, as well as background to the Mitr Lao Sugar Company has been reviewed, this sub-section will examine the economic, social and environmental impacts of the sugar cane plantation. About population and labor force, the total population of the whole case study area is about 2,065 people: about 62.3% of the population is of labor force age (15-60 years) and about 25% of the population is 14 or younger. Estimation that some people (workers) who live in rural area in Savannalhet province is still low educational level and lack of experience with industrial production. It remains a constraint for investment in the province, especially for implementing contract farming, using modern techniques and technologies, following regulations/rules and orders related to work, as well as adaptation to the province’s changing situation. According to focus group discussions, the occupational structure and livelihoods of people in the area is beginning to change. The industrial production mode and the lifestyle that accompanies it are replacing traditional livelihoods. About 2.3% of labor force in the case study area is now employed on the sugarcane plantations full-time.

5.2.1 Direct economic impacts

The most significant economic impacts of the Mitr Lao Sugar investment in the case study are “The plantation creates employment and income generation activities for local people”. According to focus group discussions, the plantation industry is an important source of additional income in the case study area. Though only 2.3% of labor force in the case study areas works fulltime on the plantations, most of the villagers in the case study area are employed in the plantation history, in some shape or form. Most are employed irregularly as day laborers. While the research team could not identify the exact percentage of the work force working part-time/irregularly on the plantations, it was clear that the majority of the labor force works on the plantations one or two weeks out of the year. As day laborers they earn about LAK 20,000 or about USD 2.4 per day. This is slightly lower than minimum wage fixed in the new regulation, i.e. LAK 569,000 per person per month, for full time work of 26 working days per month, 8 working hours a day, which equals LAK 21,885 per day. The villagers usually work in the plantation sector seasonally, after harvesting rice. According to information received in focus group discussions, full time local employees of Mitr Lao Factory earn about LAK 600,000 or about USD 35 per month. It is a little higher than the Lao minimum wage. The company also hire 103 foreign workers also the villagers use work on the plantation to supplement the income they receive through their traditional income, rather than to replace it. Most of the villagers do not want to risk leaving their traditional agricultural production to engage fully in the plantation industry. Many people in the focus groups mentioned that "the wage is too low and full employment in the plantation industry is too uncertain". According to finding s from village surveys, only about 30 people, representing about 2.3 % of the labor force in the sampling villagers, work full-time in the plantation industry. However, it does not mean that these people are fully reliant on the plantation since other households, corresponding to about 13.5 % of the total households in the three villages, have joined the contract farming scheme with Mitr Lao Sugar. According to focus group discussions and village surveys, the income from the employment in the plantation industry contributes to about 8.5 % of total household income in the sampling villages.

On reason is "The investment has contributed to a reduction in livestock production". Livestock production used to be the second most important food and income source in the case study area, after rice production. According to findings from village surveys and focus group discussions, livestock production (cows, buffaloes, pigs, chickens, ducks, etc) used to account for around 20% of household income in the area. However, the growth of the plantation has caused villages to limit their livestock production, especially large livestock like cows and buffaloes.

The focus group in Dong Ohung, Kieng Head and Na Dieng villages mentioned that many cows in their villages had died due to weight loss and no longer have regular reproductive cycles, with the villagers suspecting that of the cause is feeding on grass contaminated by chemical materials used in the plantations.

5.2.2 Direct social impacts

Based on findings from focus group discussions and village surveys in this case study area, the Mitr Lao investment project has had numerous social impacts in the three villages, including "The project has had impacts on traditional livelihoods" here it was a change of the livelihood traditional patterns of people are evident. These changes also demonstrate the strong link between environmental and social impacts in the case study area. Before the sugarcane plantations, villagers used to collect NTFPs for consumption and sale, as well as wood and straw for sale or for building after the rice harvest. Collecting timber and NTFPs was a part of the people's traditional livelihood activities as well as a course of extra income. However, as discussed above, livelihood patterns have changed, with working in the plantations as laborers now constituting a major source of additional income. This change from independent farmers to dependent employees on an industrial plantation, in which people have to follow directions, represents a substantial change for local people in the area. Participants in the focus group discussions expect that their traditional way of living will be replaced by an industrialized and modernized livelihood, which is characterized by landlessness, dependent employment and increased individuality. Local people also feel that this kind of lifestyle is more dependent and uncertain than that of before, as they become more dependent on the external world and mechanisms that they are not able to control.

"The plantations have had negative health effects for workers and the local communities". The negative health effects noted during the participatory assessment were mainly attributed to contamination and use of chemical materials, especially pesticides, without sufficient knowledge, training and equipment. Many people in the focus group discussions mentioned that: "the factory does not provide adequate information on the dangers, nor protection training and equipment to workers who spray insecticide in the sugar cane plantation." More details are provided in the environmental impacts section below. In addition, the focus groups reported many cases of illnesses in their villages. Numerous people experienced headaches, dizziness, and pains after spraying pesticides or got itchy skin after washing in the river or ponds located near to plantations. In addition, two occupational injuries were reported to have occurred in 2009. Both cases involved children that were about 12 years old.

The occupational injuries as well as the complaints about the effects of chemicals suggest that workplace health and safety is not strongly regulated in the plantations and factory. “The investment project is associated with child labor and negative effects on education.” Child labor appears to be widespread in the case study area (and it is recognized that it is not 24 uncommon in rural areas of Lao PDR more broadly). According to focus group discussions, about half of the day laborers at the sugarcane plantation are children below the age of 14 year old. People’s lack of understanding of the importance of education and the relatively low access to education contribute to this situation. Children often work to help earn extra income to support themselves and their families rather than attending school. The establishment of the Mitr Lao Sugar factory and the expansion of sugarcane plantations in the area provide school children with an opportunity to leave school to work.

5.2.3 Direct environmental impacts

The findings from the focus group discussions and village surveys in the case study area also indicate that the Mitr Lao Sugar investment project has had a number of negative environmental impacts, as described below. Importantly, the project has been implemented without having conducted an environmental and social impact assessment (ESIA) or received an environmental compliance certificate (ECC), as required by Lao Law.

About the establishment of sugarcane plantations has affected forest cover and water resources, it need substantial impacts on forest and water resources from the Mitr Lao sugarcane plantations have been felt in the case study area. According to village authorities of all three villages, over 1,420 ha of production forest, representing about 46% of the total forest area managed by Dong Phung, Keng Head and Na Dieng villages was converted into sugarcane plantations. The pictures and table below provide more detail about the changes to forest cover in the village.

The forest of Keng Head Village, which is located near to the Mitr Lao Sugar Factory, has been especially affected. More than 1,103 ha of forest, representing about 99% total forest managed by the village, was converted into sugarcane plantations. However, even if the conversion was technically legal, i.e. the conversion of degraded forests land to plantations, it is important to recognize the role of secondary or regenerating forests in supporting the livelihoods of local people. As noted above, in addition to the loss of forest environmental services, such as carbon storage, soil protection and biodiversity, decreased village forests also means the loss of forest products. It should be noted that it is unclear whether or not some of the forest that has been lost to the sugar cane plantations was provincial protection forest (meaning forest that is to be protected, such as in order to preserve a watershed area). The establishment of sugarcane plantations is also believed to have negatively affected water resources in the area. According to focus group discussion, many rivers, reservoirs and streams that used to have water during the whole year, no longer have water during the dry season.

These waterways include Hua Lhansy Chang and Tham Phung in Dong Phung Village. As noted in this project’s main report for Savannakhet Province, the relationship between forests of plantations and water flow and quality is a complex one, dependent on numerous factors, such as the species involved, local rainfall, access to irrigation, soils, and so on. However, the implications of increased investments in the natural resource sector in Savannakhet Province on its water supply and quality will require careful considerations; in particular, the potential impacts of hydropower and irrigation development are interwoven with the impacts of plantations development and the negative effects of continued forest loss and degradation.

According to MAF and the Mitr Lao Sugar company itself, the use of any chemical insecticide can be dangerous; people must have adequate knowledge and protection, such as protective clothing and gear.

The empty pesticide containers must also be buried safely. It has however exposed the area to environmental risks, such as soil depletion and water contamination due to poor soil management practices and improper chemical use, leading to environmental health issues. The costs of these environmental impacts are not fully factored within the households within their process as much of this information is not immediately known or well understood at the local level.

5.3 Direct impacts in Thailand

5.3.1 Direct socio-economic impacts

(1) Food security

Land use change might not impact on food availability because Thailand can produce rice for food and export. In 2040, paddy fields in the Thailand MRC provinces will drop by eleven percent approximately. All of these areas are unsuitable paddy fields that can be produce rice gain at 20-40 percent of optimum yield.

There is no evidence about food accessibility. However, there are many rice mills in the Thailand MRC provinces. Farmers can sell their product to the local rice mills and then distribute to local population easily.

The policy is focusing on green and clean food. This implementation will improve quality of rice product and increase the utilization of food.

(2) Farm income

Rather than increasing land, policy is focusing on increasing land productivity and quality of agricultural products. Niche market will generate more farm income.
Sugarcane can gain more farm income. Sugarcane production normally is a contact farming. Growers can gain benefit from their product sugar and sell byproducts to food (e.g., alcohol) and energy (e.g., ethanol) industries.

5.3.2 Environmental flow impacts

(1) Land resources

Forest area will increase from the policy implementation. However, there is no evidence shows that biodiversity will be better. Normally quality of plantation forest in terms of biodiversity is lower than natural forest.
Soil quality requires maintenance. Good agricultural practices will help reserve soil quality and nutrient availability.
Methane emission will decrease from paddy field because of the reduction of unsuitable paddy field. On the one hand, nitrous oxide emission will increase from field crop production.

(2) Water resources

Crop water requirement will be increase cause by the change of unsuitable paddy field to other field crop. Considering the Mekong river basin, rice requires around 4,156 m3 per hectare while maize and sugarcane require 8,268 and 12,556 m3 per hectare of water, respectively.

5.3.3 Impacts of mining

The mining and primary industries are ones of the ley industries of the country having their roles in mineral and metal explorations to feed the industry sector. The mine and primary industries are important and are links to the industry sector, leading to continuous industries that are economically high in value. Even though the number of the mining operations is not as high as other industrial operations, they are primary upstream industries. They have high impacts on the environment and the society, altering the landscape and natural resources, which are supposed to be co-owned by the general public. The mining operations also can affect environmental quality, including soil, water, and the air, that can be contaminated. The environmental pollutions can have adverse health effects. The affected land can be almost useless for agriculture (Huy, 2015).

(1) Environmental flow impacts

Basically, the mines are extracted from ores, which are compound substances. The refinement of the ores may result in the releases of some other minerals, for example, lead, zinc, manganese, and chromium, into soils and reservoirs, and be accumulated by plants. Those minerals then, in turn, are transferred to human beings directly or through food chains. For instance, the mining of the mercury may adversely affect miners and other organisms in the mine and surrounding areas.

All mines create environmental impacts from their operations. For example, the excavation results in soil leaching and erosion, turbid water resulted from the mining in the sea. Mining operations then are main obstacles in conservation of other resources as they affect soil resource, water and aquatic animal resources, forest resource, and air resource.

(2) Social impacts

Even though the industry sector, in general, is highly beneficial to the economy, it inevitably can create pollutions to surrounding areas. The mining and primary industries are one of the ley industries of the country having their roles in mineral and metal explorations to feed the industry sector. The mine and primary industries are important and are links to the industry sector, leading to continuous industries that are economically high in value. Even though the number of the mining operations is not as high as other industrial operations, they are primary upstream industries. They have high impacts on the environment and the society, altering the landscape and natural resources, which are supposed to be co-owned by the general public. They should gain the benefits resulted from mining operations. The mining operations can also cause impacts to the nearby communities, if the mining operations are not properly controlled. If they are not properly controlled, they can affect environmental quality, including soil, water, and the air, that can be contaminated. The environmental pollutions can have adverse health effects. The affected land can be almost useless for agriculture. This includes the land alteration resulting in grout and dust. The mining industry has been perceived mostly negatively by the society.

5.4 Direct impacts in Viet Nam

(1) Rain-fed agriculture

- Providing products for domestic consumption and export: The project brings economic benefits for businesses and workers. It generates a large amount of goods for domestic consumers and for export, increases capital mobilization for the state budget.
- Improve the lives of people: The project contributes to improving people’s lives in the area, especially the lives of ethnic minorities. On the other hand, it ensures security and social safety.
- Resolving labor, create jobs: The project attracts local labor force, especially ethnic minorities. It creates stable jobs for over 300 workers, contributes to reducing unemployment.
- Developing local infrastructure: The project contributes to building rural infrastructure such as electricity networks, roads, schools, clinics and social welfare facilities in the project area.

(2) Forestry project

The positive impact of the project is described as follows:

- Contribute to the economic development in the district.
- Increasing the value of land in the project area, creating a new landscape.
- Improving life for people.
- Raise people’s awareness of the importance of forests and mobilize people for forests

conservation.

The negative impact of the project is described as follows:

- Some households have to change their livelihoods, their routine is disturbed. Reduced ability to collect forest products by local people.
- Environmental pollution causes adverse effects on health workers.
- Risk of occupational accidents due to transportation, weather, dangerous animals, weapons of war remnants.

(3) Mining

The socio-economic benefits from mining activities can be included:

- Economic development of the province and locality
- Development of social and economic infrastructure, manufacturing and construction industries
- Commercial and public sector activities have improved significantly, as the generation of workers
- Creation of employment for local people

The socio-economic negative impacts from mining activities can be included:

- Resettlement of local people who live on the mining area
- Loss of forest, cover vegetation as consequence is loss of biodiversity
- Loss of fertile top soil
- Mining activities can cause air pollution, water pollution, and generation of excavated soil
- The presence of the mine has led to a rapid growth of the population through migration, which can cause social disorder, transmission of social diseases (VNMC (a), 2015).

6 Summary of findings

6.1 Summary of findings in Cambodia

(1) Rainfed agriculture and Forestry

It seems that farmers are happy with practicing rainfed agriculture (the case of cassava and maize) because its production area has been increased every year. Farmer has changed from subsistent agriculture to commercialize agriculture. Like the case of cassava, farmer traditionally cultivate around their house. However, currently the practice has changed to larger scale. Large scale of cassava or maize production that invested by Economic Land Concession Company (ELC) provided job to local community and built up road network for company utilization in the area in which this road can be utilized by local community to some extends.

For forest plantation, most of forest plantations are invested by private company, especially ELC, built up some road and providing job opportunity for local community. However, local community has been limited access to natural resources that they have been practiced from generation to generation. It seems not so clear that the impacts of forest plantation is not directly from tree species that have been planted but the main impact is about unclear boundary which lead to conflict with local community. This means that private company claimed the land from local villager and local villager claimed the land from company. However, from other studies that have been conducted in other place showed that local community devoted their land for tree planting if the land is not suitable for other crop.

Among two crops that represented rainfed agriculture, cassava and maize, cassava provide higher benefit that maize. With the discount rate of 10%, the NPV of cassava was 5 times greater than that of maize. This indicates that investing with cassava is more profitable than maize. Furthermore, investment cost of cassava is even lower than maize.

The investment in teak plantation is much more benefit than acacia. With the discount rate of 10%, the NPV for teak was 90 times higher than that of acacia. This indicates that investing with teak is more profitable than acacia even though its initial investment seems to be the largest and its rotation year is twice longer than acacia. Even the NPV of acacia is much lower than teak, but some large-scale acacia plantations have been established by private investors. This involves with many reasons such as the investors already have established markets outside companies can benefit from the whole value chains while local farmers mainly get benefits from firewood and pole.

The practice of crops production by farmers is technically inappropriate, especially in the sloping land, which leads the land susceptible to soil erosion. Furthermore, practicing monoculture on the same land for many years also leads to low soil degradation. In large scale rainfed agriculture, the impact is about converting forest land to crop land which change ecosystem structure and function.

Quite similar with rainfed agriculture, the land for forest plantation establishment has been converted from degraded natural forest. The conversion from degraded natural forest to single tree species plantation establishment will lead to biodiversity degradation. Furthermore, by converting forest land to other land use, local community who has traditionally collected NTFPs will move to deeper into the forest and leads to forest degradation in some other areas, thus impact to the environment.

Mercury and cyanide are chemicals often used in ASGM which known to have severe long-term effects on humans and the ecological system. The impact along the stream have been recorded through the death of cow that drink contaminated water from in the stream.

Technical aspect in practicing rainfed agriculture is still limited, especially farmer who planted in the sloping area. This limitation ranges from land preparation to farming system which susceptible to soil erosion. Therefore, the improvement of technology and farming system for soil management would be essential for sustainable agriculture.

The price of some forest tree plantation such as acacia is very low. This is because this price is only for fire wood or pole. If the more value added products could be developed, more benefit could be generated from this plantation. Furthermore, if improved planting materials are used for plantation establishment, more benefit could be achieved.

In addition to the above mention challenges, farmer gas face with lower price of their product. Price is fluctuated every year, especially during harvest time. For improving this challenge, contract farming with private sector would be helpful to farmer. Beside price fluctuation, most of agriculture crop, especially rainfed agriculture faces with uncertainty of climate change. Therefore, improving climate focus would be beneficial to farmer.

(2) Mining

In order to better improve the working conditions, minimize the environmental, social and cultural footprints left after the end-tenure of mining investment companies, and improve revenue transparency, it is recommended that mining companies operating in Cambodia, and the Government of Cambodian have to consider the following:

Companies operating in Cambodia

(1) Disclose to affected communities and the public information about company operations and all payment made to the government – revenue transparency can help combat corruption and ensure that mining revenue are used for the public good.
(2) Respect community rights, in particular the right of indigenous peoples to Free Prior Informed Consent.
(3) Establish community development programs for affected communities and seek community input into the design of these programs.

(4) Abide by international best practice standards, including the OECD Guidelines for Multinational Enterprises, UN Framework on Business and Human Rights, the Extractive Industries Transparency Initiative and guidelines developed by the International Council on Mining and Minerals.
(5) Companies with operational safeguard policies should ensure compliance at every stage of design, planning, operations and recovery – these guidelines should beyond the provisions of Cambodian legislation.

Government of Cambodia

(1) Complete the national legal framework guiding the extraction of mineral resources, prioritize the implementation and enforcement of national and international legislation (including re-instating that EIAs are required for exploration licenses) and revoke licenses in the case of non-compliance.
(2) New application for concessions that overlap protected areas/forests must be reviewed by the technical agency responsible for managing. Consessionaires shall be complied to reveal their revenue for public accessibility ensuring promotion of transparency and accountability in extractive industries.
(3) Compile all mineral resource deposit data and develop a national mineral resource management strategy before offering extraction rights to ensure sustainable use and mitigation of negative social and environmental impacts by providing all companies with equivalent information.
(4) Develop and implement a national policy for social and environmental responsibility in the mining sector which includes: 1) create Environmental Impact Assessment guidelines which employ multiple stakeholder participation and meaningfully fulfill their objectives; 2) ensure that all aspects of the award of rights, from pre-qualification to the implementation of contractual commitments by companies, are open to oversight by parliament and public; 3) establish an independent public agency with the mandate, resources and expertise to continuously oversee all aspects of the award of rights including the monitoring of health and socio-economic impacts; 4) develop provisions which will enable civil society groups and the wider public to have full access to information relating to the Extractive Industries Sector, according to international best practice standards including those set out by the Extractive Industries Transparency Initiative; and 5) ensure that people affected by the all activities of extractive industry sector have the opportunity for Free, Prior and Informed Consent.
(5) Ensure that all mineral issues (licensing, contracts, revenues and impacts) are fully discussed with the inter-ministerial Technical Working Group for the Development of Action Plan and Monitoring of the Implementation of Mobilization and Management of Revenue from Oil, gas and other Mining Resources to coordinate this sector to ensure maximum benefit to country and people.
(6) Issue an order requiring the cooperation and support from provincial authorities to implement and enforce the above recommendations.
(7) Urgently provide technical and financial support to relevant Cambodia government agencies to develop a national policy for social and environmental responsibility in the mineral sector.
(8) Encourage mining companies to adhere to principles of good governance, including the OECD Guidelines for Multinational Enterprises and UN Framework on Business and Human Rights, and to ensure that investments are done responsibly with minimal environmental and social harms.
(9) Provide funding support to Cambodia to help is increase transparency in the minerals sector, including to promote the Extractive Industries Transparency Initiative.

6.2 Summary of findings in Lao PDR

About Mitr Lao Sugarcane plantation company, significant amount of investment have flowed into Savannakhet Province during the last decade, likely attracted by the province's strategic location and rich natural resources. The investment flows have helped to stimulate economic growth and poverty reduction.

Savannakhet province now has a relatively high economic development status and relatively low poverty rate compared to other parts of Lao PDR. However, based on the findings from this case study on Mitr Lao Sugar's investment in Xayburi district, their investments have also contributed to negative social and environmental impacts, especially damage to forest, watersheds, biodiversity, health, education, and so on. Most importantly, the investment flowing into Savannakhet province is changing traditional livelihoods into industrial livelihoods yet without necessary improving the people's quality of life. Consequently, this study cannot say that the benefits from investments are sufficient to cover the costs.

The results from this case study also supports the argument that the investment management system in Savannakhet province needs to be improved in order to mitigate negative impacts and ensure that local communities benefit from investments. Positive satiation, it is changing lifestyle for a Lao household. For example, a head of a household, Mr. Kham, in the Xayburi district in this case study, it told us about the changes experienced by his household caused by expansion expansion of the sugarcane plantation and establishment of the sugar factory. For example, Mr. Kham's household includes six members: himself, his wife, one son, two daughters and their grandmother. Before the expansion of sugarcane plantations and the establishment of the sugar factory, the household engaged mainly in subsistence agriculture and collected NTFPs. After rice harvesting, Mr. Kham and his son would saw wood; his wife and daughters would go collecting vegetables, bamboo and mushrooms, or would cut straw for their own use and to sell. The grandmother used to stay at home and take care of livestock and cook for the rest of the family. The household had a middle socio-economic standing in the village; they were not poor and had sufficient food, an adequate house and clothes. They are still able to meet their basic needs; their livelihoods have changed but not their quality of life.

Event challenges of Rubber plantation are similar general challenges of sustainable agriculture. In Lao PDR, rubber expansion is therefore emblematic of the fundamental changes in agriculture and rural development patterns that the country is undergoing. It can be used as an entry-point to understand the larger societal process of the agrarian transition in Lao PDR and to provide cross-sectoral solutions to problems that are not specific to rubber, e.g. concessions, farmers' associations, promoting of conservation agriculture and agro forestry systems, monitoring mechanism for land use planning, environmental impact assessment and mitigation measures. As a consequences, the policy measures that will have a major influence on the rubber industry are not necessarily related to rubber but to more general mechanisms of regulation of foreign investment and patterns of development.

About the Daklak rubber plantation company, this report is possible to propose that future support for the development of commercial agriculture in Lao PDR and it should change a direction. The emphasis should be placed on the generation of direct benefits for agricultural communities rather than the allocation of large areas of land to the private sector. This study has indicated the many problems which have arisen in the case of the major land concessions studied. The projects have not begun to create the kind of economic changes that might benefit local people. As a pathway for resolving the problems arising from the loss of land to the concession companies and as a means of adjusting the direction of land management in Lao PDR, the ecological scientist and social-livelihood ethnic group balancing will propose and recommendations short, middle and long term measurements as following:

- For the short-term measures

It is possible to provide immediate relief for those suffering from the loss of land

(1) A rice fund could be established in each community that has already lost a significant area of land to the companies and have consequently experienced hunger and extreme poverty.
(2) The compensation payments must be reviewed, so that the people already affected can be compensated in as fair as a manner as possible to respect as the Decree GoL-No192/PM Compensation and Resettlement of the Development Project, 7 July 2005.
(3) Land must be found for all those who have lost their land, with a minimum of 1 ha per family for subsistence production.
(4) Wage rates for the laborers in the rubber estates must be revised and monitored to ensure that they are sufficient by which to live. Written contracts must be completed for each laborer.

- Medium term measure
  (1) Set up an official committee to monitor and investigate the implementation of all land concessions. This committee should have the following powers and responsibilities:
  (2) To monitor the companies' operations in relation to land and land use, making sure land areas are as agreed.
  (3) To ensure that local land management authorities coordinate with the labor authorities to control, regulate the labor employment fairly, so that the villages can gain regular work, fair wages and welfare at work.
  (4) To coordinate with other institutions to find alternative occupations, provide assistance and provide some relief for the families who have suffered from the loss of their land and whose wages are too low to live on.
  (5) There needs to be a land survey and land zoning plan in each province. All areas of land that are genuinely used by the communities and individuals who have been issued with certificates under the Land and Forest Allocation policy should be kept free from land concessions.
  (6) The mechanisms for the authorization of land concession should reformed to reduce the problems associated with a very complex process.

- For the long-term measures
  (1) Large-scale land concession should no longer be granted to foreign investors for commercial cropping over the long term.
  (2) Land management policy should emphasize building the capacity of people to develop their land use to increase its economic value, whereby right to use the land still belong to the people.
  (3) There should be a plan for land management which considers the balance between the benefits to the national economy, the local economy, a fair distribution of income, ecological benefits and biodiversity.
  (4) If there are to more land concessions, they should be small in scale, in land that is not subject to community use. Evaluations should be carried out of the potential impacts on the environment and society before a project is authorized.

In general, to enable workers for working in the fields of agricultural sectors and land use system management to take advantage of these opportunities, priority must be placed on ensuring basic literacy skills. Greater priority should be placed on cultivating a work force that possesses the basic fundamental skills needed to be productive. Resources need to be focused more effectively on the critical windows of opportunities when skills are built by:

- Expanding and strengthening early childhood development and education to help develop school readiness skills and basic cognitive and behavioral skills related agricultural sectors, which also includes efforts to reduce chronic malnutrition which threatens cognitive development.

- Ensuring that all children can read by the end of grade 2, making reading a national obsession so Lao PDR can build a skilled and productive workforce; and
- Building job-relevant technical skills of crop plantations, with the Government taking on a more strategic role in vocational skills development by developing policies, information about the training system, and carrying out training evaluations.

One priority for Lao PDR is to help improve the livelihoods of its large agricultural workforce by increasing productivity in the agricultural sector. With 70 percent of its work force engaged in agriculture, Lao PDR remains primarily an agrarian economy. As discussed, for economies that are categorized as “agrarian”. In the shorter term, higher agricultural productivity will help generate better livelihoods for the 4.5 million Lao people living on farms. Over the longer term, increased productivity on the farms would eventually lower the need as publication of all fee schedules, permits, and licensing requirements; and establish a more predictable playing field for the private sector, with consistent implementation of publicly available legislation, rules, and regulation.

6.3 Summary of findings in Thailand

(1) Agriculture and Forestry

This study investigates two key policies involved in agricultural land and forest change of Thailand. Base case in 2007 and two scenarios of 2020 and 2040 were formulated. Agricultural management zoning policy aims to convert unsuitable farmland especially paddy field to other alternative crops that benefits more land productivity and farm income. Approximately 22 and 75 percent of unsuitable land will be changed by 2020 and 2040 respectively. The role of natural resources and forest management policy is to enforce the law relevant to the natural resource and forest. Around 40 percent of plantation forest will be increase by 2040.

Suitability class maps of rice, maize, sugarcane, cassava and rubber, received from Thailand Land Development Department were used to analyze spatially. ALRO map was overlaid in GIS as a preserving agricultural land. Unsuitable paddy fields were selected and suitable lands of the alternative crops were selected for change. As a result, the paddy fields will decrease from 2,015,302 hectares in 2007 to 1,966,618 hectares in 2020 and 1,849,333 hectares in 2040. Sugarcane is the most extended crop. The area of sugarcane will increase 15,444 and 52,651 hectares in 2020 and 2040 respectively. Cassava also increases to 14,881 and 50,491 hectares in 2020 and 2040 respectively. Maize will increase 9,858 hectares in 2020 and 33,607 hectares in 2040. Unsuitable paddy fields will change to rubber with the area of 7,917 and 26,990 hectares by 2020 and 2040 respectively.

Protected forest, non-hunting area, wildlife sanctuary, and national park map were used to border forest areas and maintain natural resource. As a result, plantation forest will increase 8,707 and 14,511 hectares in 2020 and 2040 respectively. Suitable lands for rubber are found and can be grown 176 hectares in 2020 and increase to 293 hectares in 2040.

Other impacts of agricultural land use and forest change are expected. Food security will not be impacted by the two policies. The MRC provinces can produce enough rice for consuming and trading even though the paddy field will decrease in the future. Farm income is also expected to increase by change unsuitable paddy field to other alternative crops especially sugarcane. Forest areas definitely increase but no evidence shows that biodiversity will improve. Soil quality and GHG emission will change. Crop water requirement will increase due to the change of crops.

(2) Mining

From the study of the mining operations in 8 provinces of Thailand Mekong Basin in the 3 scenarios: 1) Early Development Scenario/Situation (2007), 2) Definite Future Scenario (2020), and 3) Planned Development Scenario (2040), there are some key findings as the followings:

- In 2007, there were 39 operated mines and 40 concessions. One mine can have more than one concession as a concession has a limited area. In 2020, there were 20 operated mines and 20 concessions. There was no information for 2040.
- In 2007, the most mined mineral was limestone (8,902,848 tons in 373.28 ha), followed by basalt (4,279,960 tons in 207.90 ha).
- In 2020, the most mined mineral was basalt (5,796,692 tons in 265.70 ha), followed by limestone (1,926,900 tons in 117.83 ha).
- All mining operations were open pit that did not use water. The water was only used for mine dressing and for spraying to contain the dust, except in the minings of the heavy metals that used water. The used water was normally recycled.
- There were 3 provinces, Amnat Charoen, Mukdahan, and Nong Khai, with no mining operation since 2007.
- It was not possible to find mining details for 2040 as the longest time for a concession was 25 years. It meant that a mine that was supposed to be operated in 2040 should have been granted in 2015 (last year), but from the search, there was no mining operation granted until 2040. However, according to the opinions of the mining experts, there should be some minerals that could still be mined in 2040, for example, some industrial rocks (such as limestone, basalt, granite, and sandstone) and iron. At present, the price of the iron was decreasing rapidly. Some iron mined were stopped operationg. If its price increases again in the future, the iron mines may be operated again.
- According the GIS file of Department of Primary Industries and Mines, Ministry of Industry, the number of the mines has been decreasing. In 2007, there were 56 mining concessions in the 8 provinces, but it was 46 in 2015. In 2020, there have been 26 granted mining concessions. There were several factors resulting in the decreasing of the operate mines. There were 1) the declining of the minerals, 2) govern policies, 3) raising awareness of the communities about the environment, 4) global and national economic situations. Also, some mines could not be operated, despite granted, due to a number of reasons, for example, price, market demand, economic situations of the mining operators, and community resistance.
- According to the Mineral Statistics of Thailand (2003-2014), the mining production, consumption, and import, had been increasing, but the export has been decreasing.
- Department of Mineral Resources had a project to survey the country's mineral reserves in 2016.
- Thailand would change to be an investor in mining operations in neighboring countries, especially ASEAN countries.
- In the future, the Thailand's national plans/strategies would be emphasized on effective utilization of the minerals and environmental-friendly production.

6.4 Summary of findings in Viet Nam

(1) Rainfed agriculture

From an economic perspective, the rubber plantation project in Ia Blu commune, Chu Se district, Gia Lai province is clearly financially very attractive considering the high price of rubber on the international market. The 847 ha of plantations established between 2008 and 2014 are a technical success. The NPV was estimated at USD 14,581,025 (USD 17,215 per ha) over a 33-year period (2008-2040) with a discount rate of 10%. Considering social perspective, it is undeniable that the project has the potential to contribute significantly to the socio-economic development of the project area such as improving the lives of people, resolving labor, creating jobs for over 300 workers, developing local infrastructures. Besides, the project also has environmental impacts (both positive and negative) in three phases of the project: (1) reclamation, site preparation, (2) planting care of rubber trees and latex extraction, (3) rubber trees liquidating.

(2) Forestry

From an economic perspective, the results of the study indicate that there are significant potential net benefits from the forest conservation project of Cu Jut Forest Enterprise, Ea Po commune and Dak Win commune, Cu Jut district, Dak Nong province (with a NPV of USD 27,245 per ha over a 30-year period with a 10% discount rate). Considering social perspective, the project contributes to improve life for people as well as promote the economic development of Cu Jut district. It also raises people's awareness of the importance of forests and mobilize people for forests conservation. However, environmental pollution and risk of occupational accidents could causes adverse effects on health workers. For the environment, excluding the negative impact of carbon storage, the project has the potential negative impacts such as excessive soil erosion, loss of soil fertility, risk of pest infestation and disease, loss of biodiversity, fire risk.

(3) Mining

From an economic perspective, the financial analysis of the sand mining project in An Binh commune and Dong Phu Commune, Long Ho district, Vinh Long province shows that the private profit from sand mining is large. The 0.175 km^2 project can earn as much as USD 65,170 per year. However, based on the findings from this case study, the project has also contributed to negative social and environmental impacts, especially damage to public health, water traffic, ecosystems quality, etc.

7 Scope of the assessment

The Geographic scope of the irrigation impact assessment is based on the SIMVA Corridor shown in Figure 14.

Figure 14: Council Study impact assessment corridor. Same as used in the MRC Social Impact Monitoring and Vulnerability Assessment, or SIM/VA, of the Environment Programme.

The modelling results have been processed for the SIMVA zones used in the socio-economic analysis (**Figure 15** and Table 14). Two additional zones 6B and 6C (**Figure 15**) have been added as requested by Vietnam.

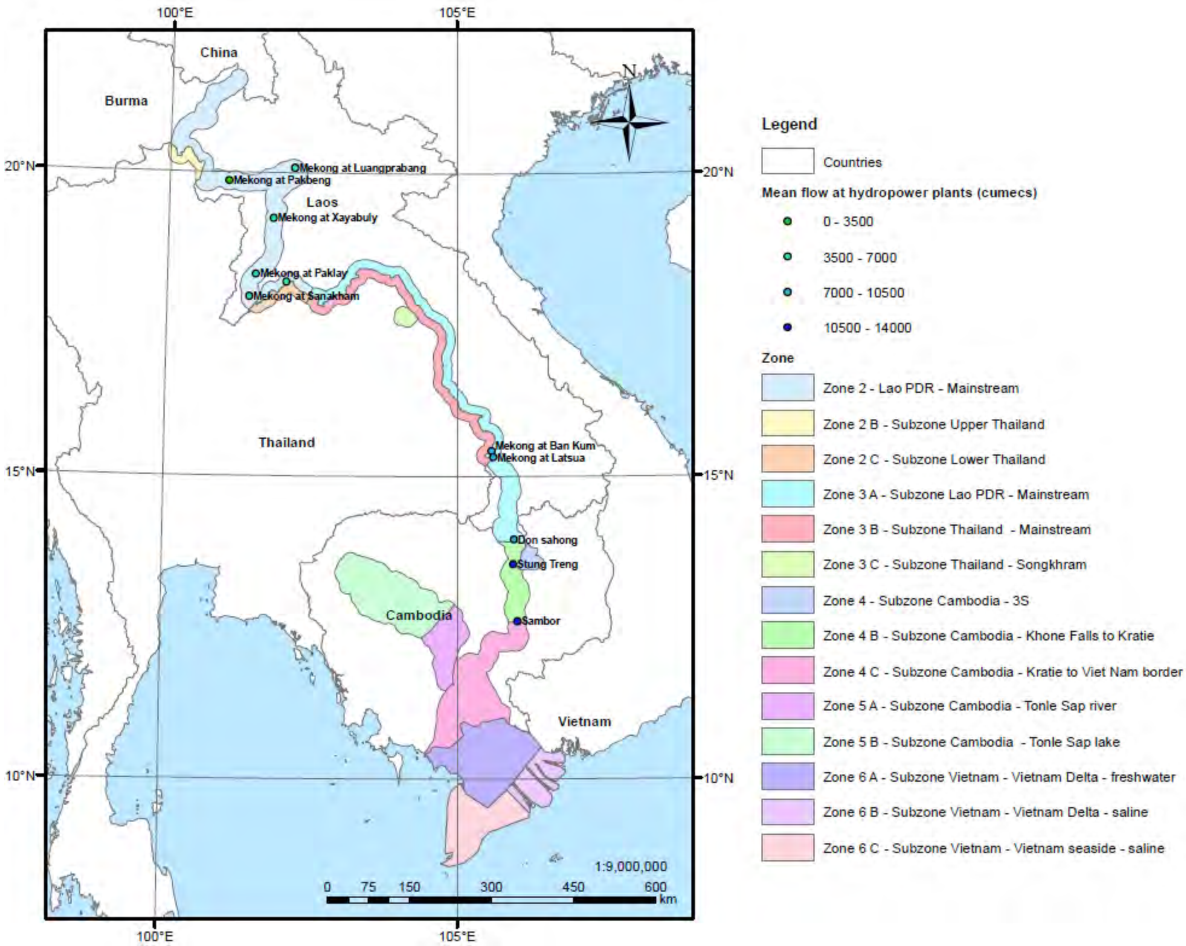


Figure 15. Model output areas for the socio-economic analysis

The design of the assessment for main and sub- development scenarios can be observed in the Cumulative Impact Assessment Report (The Council Study Core Team, 2017).

Table 14: Description of the SIMVA zones used in the model analysis and socio-economic study

SIMVA Hydro-ecological zone	Description: IBFM	Description: SIMVA	Social survey Sub-zones	Description
Zone 2	From Chinese border to Vientiane (Upstream)	From Chinese border to Vientiane (Upstream)	Zone 2 - Lao - Mainstream	Lao PDR side of Zone 2
			Zone 2 B - Subzone Upper Thailand	Thai side of Zone 2 in 2 significantly different Sub-zones: Upper stream in Chiang Rai and Phayao Provinces and Lower stream west of Vientiane in Loei and Nong Khai provinces
			Zone 2 C - Subzone Lower Thailand	
Zone 3	From Vientiane to Pakse	From Vientiane to Lao-Cambodian border	Zone 3 A - Subzone Lao - Mainstream	Lao side of zone 3 along the Mekong mainstream (incl. Vientiane)
			Zone 3 B - Subzone Thailand - Mainstream	Thai side of zone 3 along Mekong mainstream
			Zone 3 C - Subzone Thailand - Songkhram	App. 40 km upstream from confluence of Songkhram and Mekong – wetland areas and undammed river
Zone 4	From Pakse to Kratie	From Lao-Cambodian border to Cambodian Viet Namese border	Zone 4 B - Subzone Cambodia - 3S	App. 40 km from confluence of 3S and Mekong – undammed river, special eco-system
			Zone 4 A - Subzone Cambodia - Khone Falls to Kratie	Along Mekong mainstream down to start of floodplain
			Zone 4 C - Subzone Cambodia - Kratie to Viet Nam border	A 15 km zone around the maximum flooded area on the floodplain along the Mekong mainstream and Bassac east and south of Phnom Penh
Zone 5	From Kratie to Phnom Penh (upstream), incl. Tonle Sap	From Phnom Penh up to and including Tonle Sap lake	Zone 5 A - Subzone Cambodia - Tonle Sap river	The socio-eco system of Tonle Sap river is considered different from the Lake so a special subzone has been drawn
			Zone 5 B - Subzone Cambodia - Tonle Sap lake	The area is defined as 15 km around the maximum flooded area (in year 2000)
Zone 6	From Phnom Penh to Mekong Delta.	From Cambodian-Viet Namese border to sea - the Mekong Delta	Zone 6 A - Subzone Viet Nam - Mekong Delta - freshwater	The subzone covers the area of the Mekong Delta which has freshwater
			Zone 6 B - Subzone Viet Nam - Mekong Delta - saline	The saline subzone has special characteristics such as problems with saline intrusion

The Council Study modelling is set up for the whole basin to account for its hydrology and different development interventions.

As defined by the Inception Report and the logical framework in the Implementation Plan, the ALU study and this ALU Report highlight:

- Forested area, non-irrigated agriculture, wetland, floodplain and urban expansion impacts on river flow in terms of quantity, quality, timing and content (i.e. sediments, nutrients, etc.)
- Resulting transboundary positive and negative impacts on environmental, social and economic parameters
- The changes in sediment transport linked to land-use change and erosion will be a key section in this report
- Impacts of other developments on wetlands and floodplains caused by infrastructure development, climate change and flood pulse and sediment/nutrient input changes.

8 Data collection and the development scenario definitions

8.1 Data collection and harmonization from the Member Countries

Irrigation data collected from member countries by the ALU Thematic Team is on provincial level. Cambodia, Lao PDR and Vietnam provided data for the entire watershed area for the year 2007 and Thailand provided data for the Council Study assessment corridor. The collected landuse type data consists of three types: forest, rainfed agriculture and mineral mining. The collected data required significant processing as:

- Data from all Member Countries doesn't cover the whole watershed and modelling area
- Landuse classifications are not fully consistent between the countries
- Landuse classification is not fully consistent with the MRC Landuse data base for 2003 and 2010
- Changes in other types of land use than forest and agriculture are not provided
- Urban expansion data has not been provided.

Landuse data review and analysis has provided following conclusions:

Cambodia:

- Year 2007; forest area was missing in some provinces such as Pheah Vihear, Pursat, and total forest area is less than MRC Land use database in 2003 and 2010
- Dev 2020; forest and agriculture area was missing in most of the provinces
- Dev 2040; only forest plantation area was provided
- No data of other land use types such as flooded forest and urban areas.

Lao PDR:

- Year 2007; no data of forest area were provided but agriculture area was provided in detail for rainfed rice and field crops
- Dev 2020; forest and agriculture area was provided enabling comparison area change with MRC database in year 2010
- Dev 2040; no data provided
- Other landuse type such as urban, water and other area was not provided

Thailand:

- Year 2007; Forest area in 8 Provinces along Mekong was provided including detailed data for agriculture and other land use; however, information is lacking inside basin from 17 provinces
- Dev 2020 and Dev 2040; forest and agriculture area was provided for 8 provinces that can be used to estimated landuse change trend for the other provinces
- Other landuse types such as urban, water and other classes was provided
- Verified data shows that forest area in each province is unchanged (or change is very small) corresponding to the national policy; the only significant change is expansion of irrigation in the existing agricultural areas.

Vietnam:

- Highland
  - Year 2007 and Dev 2020; forest area was provided and showing reduction of forest area and change crop land
  - Dev 2040; forest area in Highland was not provided.
- Delta
  - Year 2007 and Dev 2020; forest area was provided showing reduction in forest area

- Dev 2040; forest area in delta in most of the provinces was provided while missing in some provinces such as Hau Giang, Cantho and Vinlonh; however, the change is small
- other landuse class information was not provided such as aquaculture or urban area.

8.2 Scenario data gap filling

The methodology for 2020 and 2040 data gap filling after harmonization of the land use classification from different sources is (Vonnarart, O. and Nguyen Dinh, D., 2017):

1. Estimation of Land Cover/Landuse change from MRCS database (year 1993, 1997, 2003 and 2010)
2. Estimation of Land Cover/Landuse change from 2007, 2020 and 2040 based on data from MC (collected by the ALU Thematic Team)
3. Forecasting of annual change (%) between the years 2007, 2020 and 2040; this step is based on annual rate change from LU change from MC; if the change cannot be estimated, change based on the MRC database is applied
4. Estimation of area (ha) for forest and agriculture for the years 2003/2007, 2020 and 2040.

The step 3 gives development scenario land use percentages:

Table 15: Estimated scenario land use change in %. (ref. GAP filling report)

Country	Land Cover Types	Annual change in Percent (%)			Assumption for using data	
		2007	2020	2040	For year 2020	For year 2040
Cambodia	Forest		*-2.67%*	0.00%	Use annual rate from LU change 2003 / 2010 (MRC database) from 2003-2016 (present year), then apply no change based on country policy	no more reduce of Forest based on country policy
	Agriculture				Expand based on reducing of Forest area	Expand based on reducing of Forest area
Lao PDR	Forest		0.17%	0.17%	Use annual rate from LU change 2007 / 2020	Use annual rate from LU change 2007 / 2020
	Agriculture		0.40%	0.21%	Use annual rate from LU change 2007 / 2020	Use annual rate from LU change 2020 / 2040
Thailand (8 Provinces)	Forest		0.03%	0.02%	Use annual rate from LU change 2007 / 2020	Use annual rate from LU change 2020 / 2040
	Agriculture		-0.03%	-0.01%	Use annual rate from LU change 2007 / 2020	Use annual rate from LU change 2020 / 2040
Vitenam -HighLand	Forest		-0.41%	-0.41%	Use annual rate from LU change 2007 / 2020	Use annual rate from LU change 2007 / 2020
	Agriculture		0.49%	0.49%	Use annual rate from LU change 2007 / 2020	Use annual rate from LU change 2007 / 2020
Vitenam -Delta	Forest		-0.94%	0.44%	Use annual rate from LU change 2007 / 2020	Use annual rate from LU change 2020 / 2040
	Agriculture		-1.28%	0.00%	Use annual rate from LU change 2007 / 2020	No more change in Agriculture area, based on limited of area

The step 4 gives landuse areas:

Table 16: Estimated scenario land use areas. (ref GAP filling report)

Country	Land Cover	Area - Ha			
		2003 * (represent year 2007)	Reestimated year 2010	2020	2040
Cambodia	Forest	8,303,852	6,939,094	5,949,295	5,949,295
	Agriculture	3,719,442	5,084,200	6,073,999	6,073,999
Lao PDR	Forest	17,379,583	17,589,152	17,892,927	18,516,307
	Agriculture	1,925,550	1,979,877	2,060,156	2,148,168
Thailand	Forest	4,133,540	4,143,652	4,158,142	4,170,693
	Agriculture	13,484,104	13,459,248	13,423,818	13,391,904
Vitenam - HighLand	Forest	1,976,453	1,698,986	1,630,781	1,630,781
	Agriculture	464,262	1,412,100	1,482,240	1,482,240
Vitenam - Delta	Forest	227,666	213,067	193,821	211,415
	Agriculture	2,592,771	2,369,514	2,083,509	2,083,509

Year 2003* is based on database using in DSF model

The forest and agricultural area changes are shown in the graphs below.

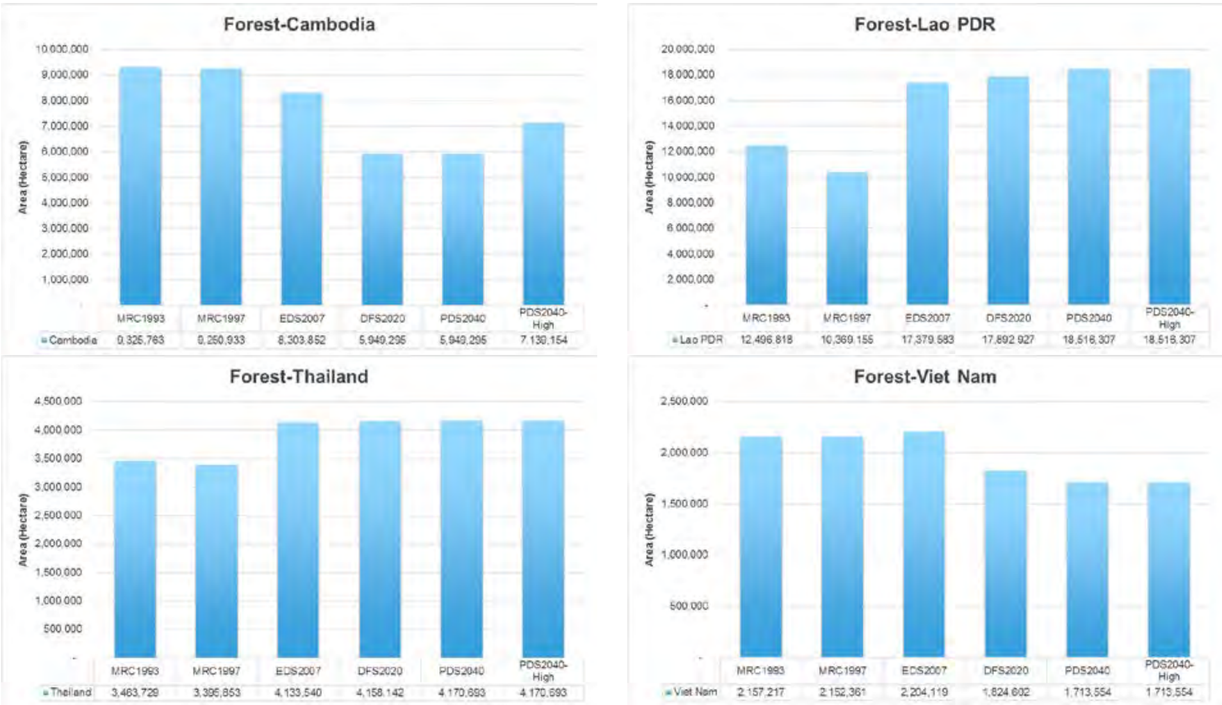


Figure 16: Historical and estimated development forest area changes.

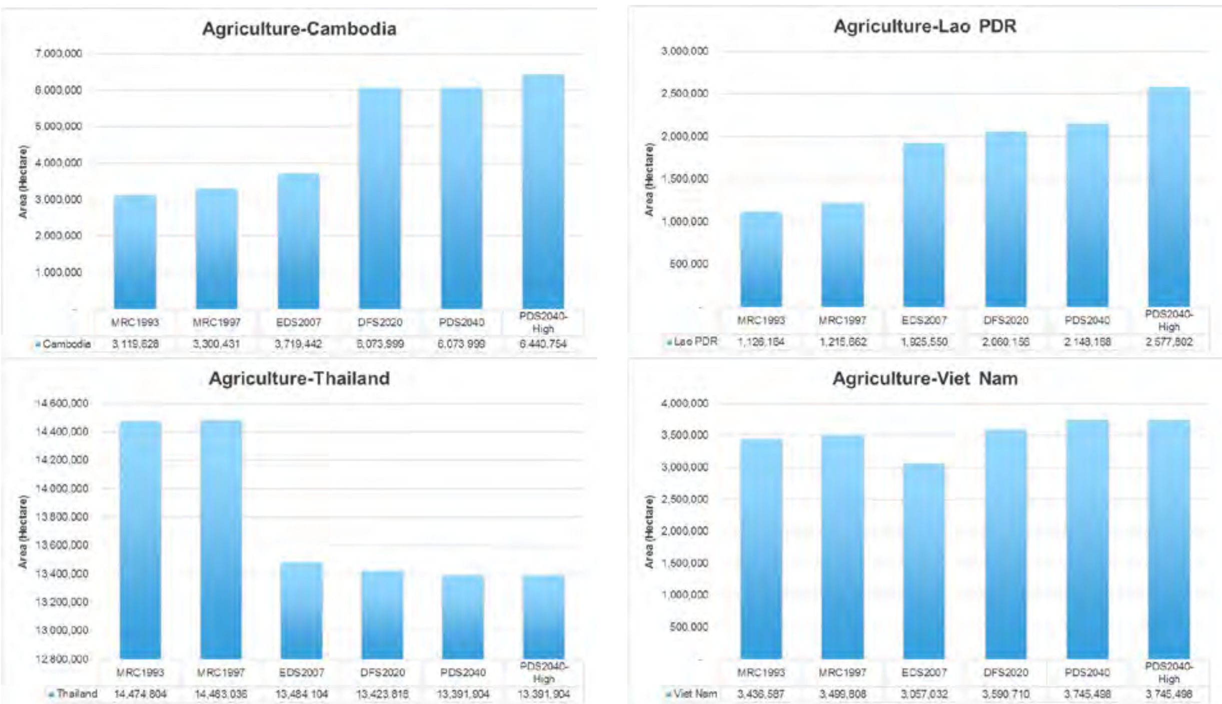


Figure 17: Historical and estimated development agriculture area changes.

Description of the data collection and compiled data sets are presented in the Irrigation Team report "Thematic Report on the positive and Negative Impacts of Irrigation on the Social, Environmental and Economic Conditions of the LMB and Policy Recommendation." Data collection for the ALU scenarios are described in the report "Thematic Working Paper on Development Scenarios Agriculture and Land Use

Change." Country data collection and data gap filling methodology is described in detail in the Modelling Team report "Data Analysis and GAP Filling for Model Simulation." The ALU data gap filling methodology chapter from this report is included in the ***ANNEX I.***

8.3 New Cambodian forest cover data

A new study of forest cover historical development in Cambodia was completed by the end of 2017. The study shows that actual historical deforestation numbers that were obtained and estimated before are too high. Reforms in Cambodia such as reforestation, communal forestry, and forest protection measures have reduced forest loss rate compared to what was estimated previously. Based on the latest numbers provided at the 10th RTWG (during 7-9 December 2017), 2016 forest cover in Cambodia is 8,196,440 ha. Or 45.6% of total country forest. The loss is due to agriculture expansion, mining clearance, and construction and rehabilitation of irrigation systems.

As the new data has been available at the end of the Council Study it has not been possible to update most of the study including GIS map preparation, modelling and ALU report. This is not undermining the modelling and conclusions as the overall impact of the new Cambodian forest cover numbers are quite small to hydrology and sediments. However, the impact is large to the macro-economic analysis as the forest cover relates to natural capital and ecosystem services. Because of this the macro-economic report has been updated with the new forest cover numbers provided by Cambodia.

Furthermore, 2016forest cover (48%, 8,742,401 ha) was re-confirmed by the Ministry of Environment during the Stakeholder Forum (14-15 Dec 2017). Due to the time limitation, there could not be re-analysis, however, the team did calculate this additional case and insert in the footnote of Chapter 19 and in the macro-economic report that "Recent discussions in Cambodia instigated reforestation plans that target a forest cover of 48% (or 8.7 m ha), which would translate into an overall improvement of the average net present value of natural capital to +$93 billion (MIN: +$47 billion and MAX: +$138 billion)". In this case, it shows that if Cambodia can maintain forest areas as in 2016 situation in the future following the national plan and policy of reforestation and forest conservation, they can gain the natural capital and finally leads to reduction of loss in the net present value accumulated from all sectors.

8.4 Sub-scenarios

The land use main scenarios and sub-scenario A2 are defined in the Table 17. The sub-scenario A1 is defined with the 2007 agricultural area but is otherwise same as the M3CC. Also A2 is based on the M3CC conditions except for the land use. The main scenario data is based on the data obtained from the member countries and data gap-filling (see Chapter 8.2). In addition to the main scenarios one sub-scenario, HIGH, has been defined as highest level of the forest and agricultural areas expansion in 2040. As there is no collected data from the countries on the HIGH scenario, assumptions need to be used. The assumptions are:

- All MCs have policies to either conserve existing forests or promote reforestation
- The HIGH development 2040 is higher than PDS 2040 by 20%
- Shrubland has potential to be improved and converted to forest area
- Grassland and bare land have potential to be improved and converted to agriculture area
- The conversions need to consider total land area and land suitability in each country
- If potential areas for agricultural conversion are located in steep slopes or areas that are not suitable for agricultural practices they are not converted
- Urban expansion and annual crop plantation expansion have priority over other changes
- Increasing land capacity to have more than one crop per year will be considered as irrigated agriculture in irrigation sector. These areas are not considered in the ALU sector to avoid double counting areas.

Table 17: Definitions for the land use main and sub-scenarios

Country	Land Cover Type	Area (Hectare) Main Scenarios ED2007	DFS2020	PDS2040	Sub Scenario Available and potential areas of conversion	HIGH Development 2040**	Remarks
Cambodia	Forest	8,303,852	5,949,295	5,949,295	-	7,139,154	Assume that Cambodia will have a policy to develop forest areas/reforest more 20% of the PDS2040. The shrubland will be improved and coverted to forest.
	Rain-fed agriculture	3,719,442	6,073,999	6,073,999	-	6,440,754	Assume that grasslands will be utilized and converted to agriculture areas. However, the figure can be less than the proposed figure (6,440,754) if during the modeling process, we found that the coverted lands are on high steep slope or not suitable for agricultural practices. For agriculture cannot use the criteria of 120% due to the limitation of available land.
	Shrubland	-	-	-	1,393,309	-	
	Grassland and bared land	-	-	-	366,755	-	
Lao PDR	Forest	17,379,583	17,892,927	18,516,307	-	18,516,307	Assume that the forest areas are maintained. The PDS2040 includes all potential policies for forest conservation in Laos. The current figure is almost 90% of Laos' area in LMB.
	Rain-fed agriculture	1,925,550	2,160,023	2,148,168	-	2,577,802	Assume that Laos will expand agricultural areas more 20% of the PDS2040 to support food security and export of the country. Grasslands will be utilized and converted to agriculture areas. However, the figure can be less than the proposed figure (2,577,802) if during the modeling process, we found that the coverted lands are on high steep slope or not suitable for agricultural practices.
	Shrubland	-	-	-	5,079,809	-	
	Grassland and bared land	-	-	-	573,142	-	
Thailand	Forest	4,133,540	4,158,142	4,170,693	-	4,170,693	Existing areas are used in high capacity and very small areas are left for conversion. Therefore, the assumption will be rain-fed agricultures are increased their capacity by irrigation, which are included in HIGH development in IRRIGATION sector. The available areas are expected for urban expansion/development, which are included in
	Rain-fed agriculture	13,484,104	13,423,818	13,391,904	-	13,391,904	
	Shrubland	-	-	-	468,824	-	
	Grassland and bared land	-	-	-	226,104	-	
Viet Nam-Highland	Forest	1,977,367	1,630,781	1,630,781	-	1,630,781	Similar to Thailand, existing areas are used in high capacity and very small areas are left for conversion and with higher capacity in irrigation. The available areas are expected for urban expansion/development, which are included in INDUSTRIAL sector. Also, the current situation of expansion of aquaculture and perrenial crops such as tea and coffee leads to limitation of available converted to rain-fed agriculture.
	Rain-fed agriculture	464,262	1,482,240	1,482,240	-	1,482,240	
	Shrubland	-	-	-	4,896	-	
	Grassland and bared land	-	-	-	41,393	-	
Viet Nam-Delta	Forest	227,666	193,821	211,415	-	211,415	
	Rain-fed agriculture	2,592,771	2,083,509	2,083,509	-	2,083,509	
	Shrubland	-	-	-	376	-	
	Grassland and bared land	-	-	-	4,223	-	

(*) For scenario development, the modeling includes only rain-fed agriculture and forest lands
(**) All converted areas will have to consider land suitability during the modeling process. If converted lands are not suitable, they will be maintained same as the previous land cover type.

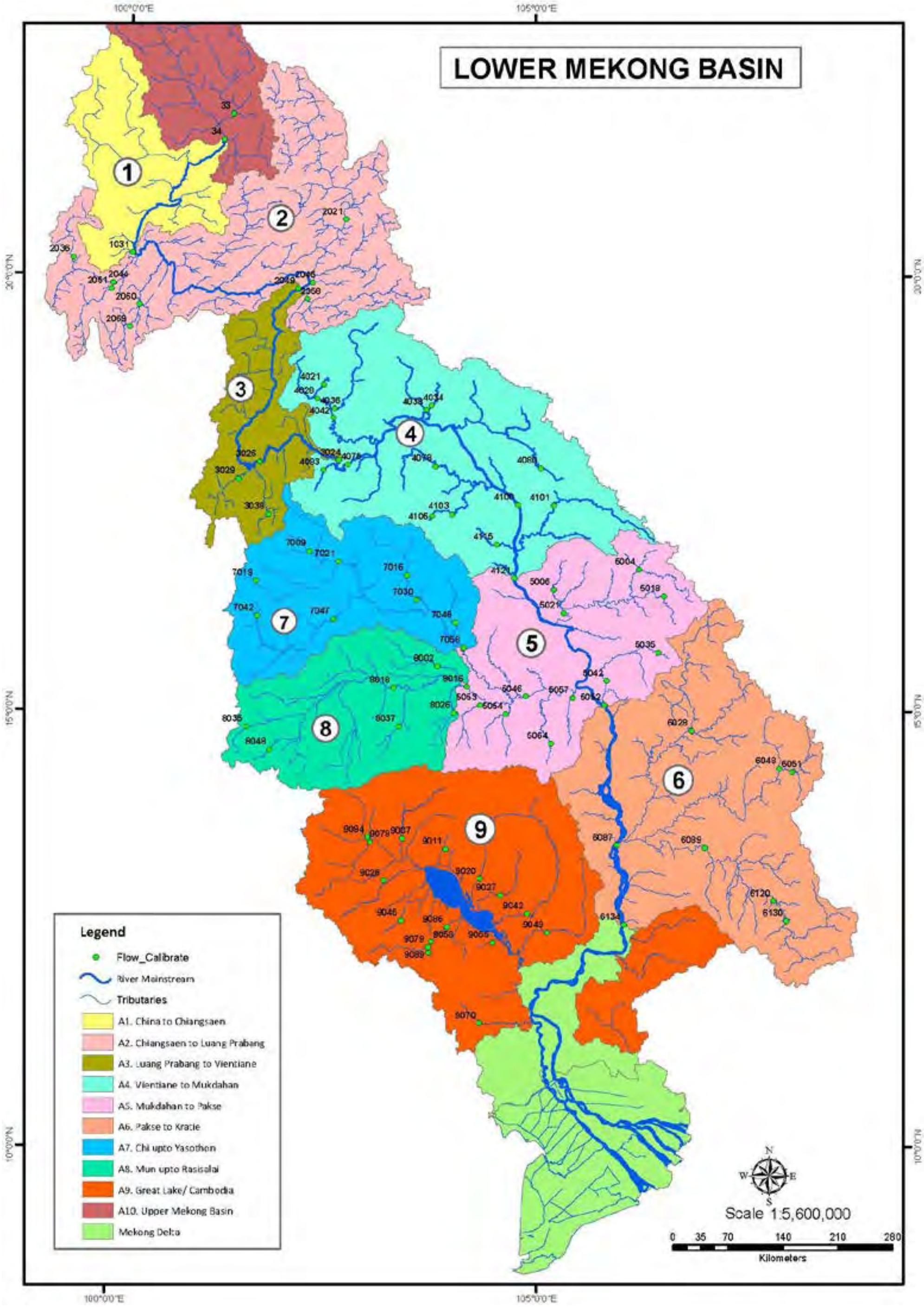


Figure 18: SWAT sub-model areas. (ref. SWAT Modelling Report)

The forest and land use areas for the scenarios M3CC (2040 climate change), A1 (2007 land use) and A2 (high agriculture development) are shown in the Table 18. The SWAT sub-model areas indicated in the table are shown in the Figure 18.

Table 18: Comparison between agriculture area between the scenarios M3CC, A1 and A2. (ref. SWAT Modeling Report)

SWAT area	Scenario	Forest-Ha	Agriculture-Ha	PREC- mm
Area 0	M3CC			
China	A1			958
	A2			958
Area 2	M3CC	25,571	760	1,666
	A1	25,520	822	1,666
	A2	25,571	760	1,666
Area 2	M3CC	14,121	7,450	1,589
	A1	13,387	7,453	1,588
	A2	14,121	7,450	1,588
Area 3	M3CC	11,114	4,805	1,574
	A1	10,181	4,699	1,572
	A2	11,114	4,805	1,572
Area 4	M3CC	29,540	27,186	2,127
	A1	27,916	26,651	2,121
	A2	29,540	27,723	2,130
Area 5	M3CC	24,080	31,484	1,774
	A1	23,160	31,180	1,773
	A2	24,059	31,627	1,774
Area 6	M3CC	70,206	21,612	2,086
	A1	80,170	8,547	2,076
	A2	71,003	21,646	2,080
Area 7	M3CC	9,609	32,837	1,266
	A1	9,609	33,002	1,266
	A2	9,609	32,837	1,266
Area 8	M3CC	5,097	36,867	1,129
	A1	5,097	37,124	1,129
	A2	5,097	36,867	1,129
Area 9	M3CC	34,694	61,980	1,349
	A1	56,931	40,919	1,304
	A2	38,052	62,515	1,344

Table 19 summarizes the main scenario and A1- and A2-subscenario areas for the countries. It can be seen that the largest agriculture expansion is in between 2007 and 2020 for both irrigated and rainfed agriculture. Irrigated area continues to expand between 2020 and 2040 but it has only negligible impact on rainfed agriculture area.

Table 19: Comparison between agriculture area between the scenarios M3CC, A1 and A2.

Country	Irrigated rice (Ha)	Rainfed agriculture (Ha)	Sum (Ha)
Deve 2007 & A1			
Cambodia	273'337	3'719'442	3'992'779
Lao PDR	209'116	1'925'559	2'134'675
Thailand	776'980	13'484'104	14'261'084
Viet Nam	1'719'130	1'464'262	3'183'392
Total LMB	**2'978'563**	**20'593'367**	**23'571'930**
Dev 2020			
Cambodia	456'837	6'073'999	6'530'836
Lao PDR	309'068	2'160'023	2'469'091
Thailand	1'544'296	13'423'818	14'968'114
Viet Nam	1'701'148	1'482'240	3'183'388
Total LMB	**4'011'349**	**23'140'080**	**27'151'429**
Dev 2040			
Cambodia	678'030	6'073'999	6'752'029
Lao PDR	597'893	2'148'168	2'746'061
Thailand	1'810'650	13'391'904	15'202'554
Viet Nam	1'674'915	1'482'240	3'157'155
Total LMB	**4'761'488**	**23'096'311**	**27'857'799**
A2			
Cambodia	273'337	6'440'754	6'714'091
Lao PDR	209'116	2'577'802	2'786'918
Thailand	776'980	13'391'904	14'168'884
Viet Nam	1'719'130	1'482'240	3'201'370
Total LMB	**2'978'563**	**23'892'700**	**26'871'263**

9 Assessment indicators

The Inception Report and Thematic Team output logical framework presented in the implementation plan define the key indicators/outputs for the ALU as:

- Timeline for land use
- River flow including timing
- Water quality
- Sediment transport
- Nutrient transport.

The indicators are further grouped into a) environmental, b) socio-economic and c) transboundary indicators:

a) Impacts of flow and nutrient loads on environment:
   - Water quality
   - Saline intrusion
   - Biodiversity
   - Fisheries production
   - Wetland and floodplain areas.

b) Socio-economic indicators include:
- Impact of flow changes on social, economic and employment indicators
- Expected impact on food production/food security
- Household/farm income

c) Transboundary indicators include:
- Impact of flow changes on transboundary benefits and costs

The different models used for the above indicators are listed in the Table 20.

Table 20: ALU indicators and corresponding models used in the Council Study

Indicator	Model	Justification
Timeline for land use	None	Model input data
River flow including timing	ISIS (inputs from SWAT & IQQM)	Hydrodynamic model for flow
Water quality	DSF; IWRM	DSF required for whole watershed and river channel water quality; IWRM model for specific BioRA indicators based on the DSF results
Sediment transport	DSF; IWRM	DSF required for whole watershed and river channel water quality; IWRM model for specific BioRA indicators based on the DSF results
Nutrient transport	DSF; IWRM	DSF required for whole watershed and river channel water quality; IWRM model for specific BioRA indicators based on the DSF results
Saline intrusion	ISIS; IWRM	ISIS required as salinity intrusion is hydrodynamically based; IWRM model for specific BioRA indicators based on the ISIS results; IWRM also for saline intrusion impacts on rice yields
Biodiversity	DSF; IWRM; DRIFT	Both DSF and IWRM provide indictors for BioRA biodiversity assessment
Fisheries production	DSF; IWRM; DRIFT	IWRM model using DSF results (water levels, sediments) for computing fish biomass; BioRA DRIFT expert assessment methodology for ecologically based fisheries assessment
Wetland and floodplain areas	ISIS; IWRM	ISIS provides water levels in the river channels; IWRM translates these into flooding indicators which in turn are used in the wetland and floodplain assessment by BioRA. Flooding indicator for distinguishing different floodplain vegetation types has been developed and verified (ref. WUP-FIN

Indicator	Model	Justification
		modelling report). This can be used in the future to study wetland changes.
Socio-economic indicators	DSF; IWRM; DRIFT	All models provide data for the socio-economic assessment; IWRM integrating DSF for socio-economic and BioRA DRIFT indicators; crop yields and fish production are the main model outputs for the S-E assessment
Transboundary indicators	DSF	DSF models compute transboundary flow changes

10 Assessment Methodology

10.1 List of thematic outputs and corresponding methods

ALU thematic outputs and corresponding methodologies are listed below. The outputs are specified in the Council Study Inception Report and the Implementation Plan logical framework (Table 1 and text).

Timeline of non-irrigated agriculture, forest and urban areas:

- Basic data from national consultations
- Gap filled by the modelling team (see above).

Timeline of wetland and floodplain areas:

- Extrapolation of land cover change between 2000 and 2010 (MRC land cover data)
- MRC reports on wetlands (BDP, EP, IWRM, CCIA) and floodplains (FMMP, IWRM).

Changes in river flow including timing; water quality; nutrient transport:

- Data from the Modelling Team.

Impact of other sectors' development on wetlands and floodplains:

- Flood protection thematic team data on floodplain infrastructure development including channels, dykes and roads
- Modelling team data on hydrology (e.g. ground and soil water), flooding and sediment/nutrient inputs to wetlands and floodplains.

Impact of changes to hydrology, flow and sediment/ nutrient loads on environment:

- Data from modelling and BioRA including
    - Water quality
    - Saline intrusion
    - Biodiversity
    - Fisheries production
    - Wetland and floodplain areas.

Impact of changes to land use, flow and sediments/ nutrients on social, economic and employment indicators:

- Data from the Socio-economic Team.

Impact on food production/food security including agriculture and ecosystem services:

- Crop yield modelling

- Data from socio-economic, bio-assessment and modelling discipline teams.

Impact on household/farm income:

- Data from socio-economic discipline team.

Impact of flow and water quality changes on transboundary benefits and costs:

- Who:
    - Farmers
    - Fishermen
    - Domestic and industrial water users
- What benefits and costs:
    - Increased/decreased agricultural yields
    - Increased/decreased fisheries production
    - Increased/decreased water availability and water treatment costs
- Data from modelling and S-E teams.

10.2 Preparation of the land use change maps

DSF modeling (SWAT) is based on the MRC 2003 land cover map. In the impact modeling and socio-economic assessment, the land use base map is the 2007/2010 MRC land cover map. The base map has been checked for data consistency and reliability as well as harmonized the impact modeling and socio-economic analysis. In addition, the base map has been developed for the 2020 and 2040 main scenario and 2040 HIGH sub-scenario land use change. The information required for development are slope raster map, land use raster map, sub-basin boundaries and modelling team land use change tables (see Chapter 7 above).

10.2.1 Slope

The first element considered was the slope which was obtained from a 30 m X 30 m resolution digital elevation model (DEM) the CGIAR-CSI (Consortium for Spatial Information). The DEM has been processed and corrected from the ASTER GDEM and NASA STRM remote sensing data. 30 m X 30 m resolution slope map was created based on the CGIAR DEM. The two resulting maps are shown in the Figure 19.

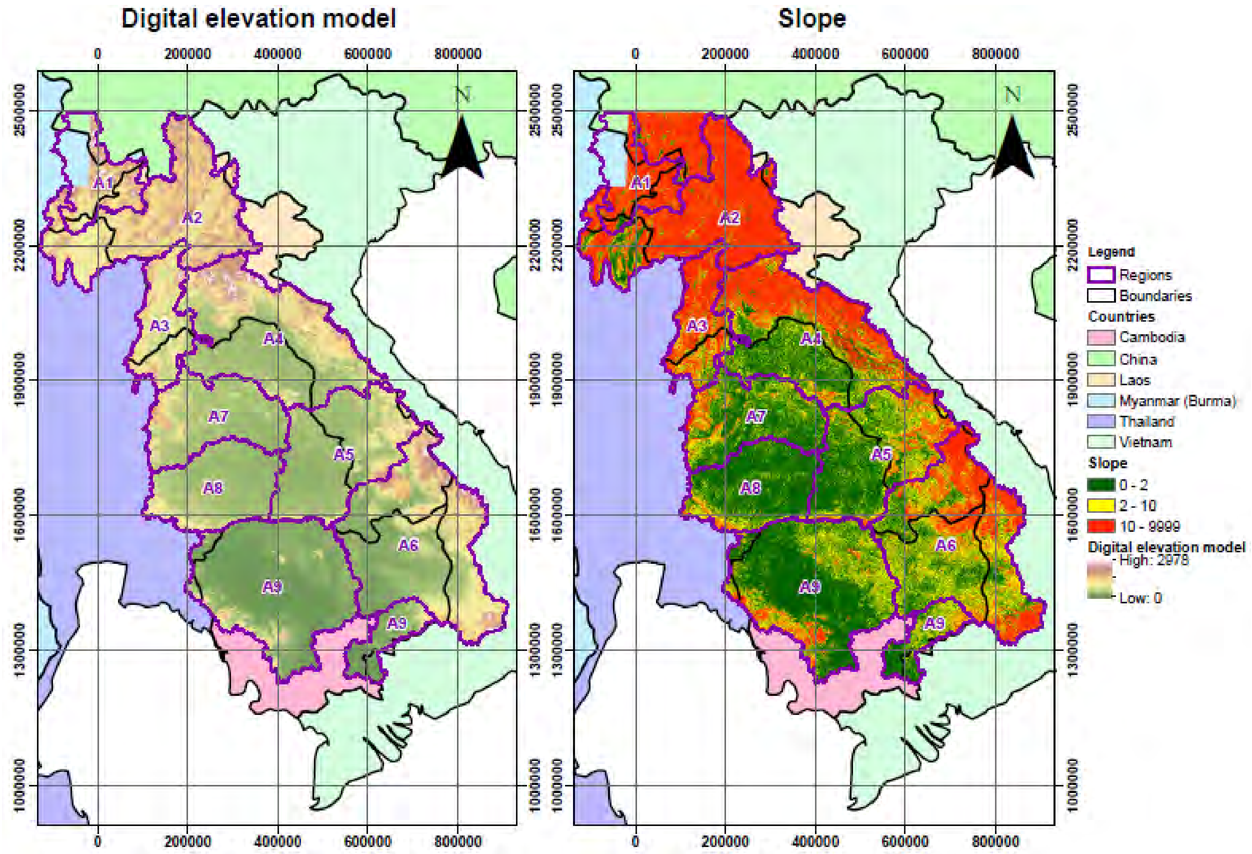


Figure 19. DEM and slope (grade) maps for the Mekong River within the regions

The figure above shows that Khorat plateau in Thailand has between 0 – 2 slope while mountainous higher elevations indicated by red color have slope between 10 and 9999. For the 2040 HIGH sub-scenario (Chapter 8.4) land use map preparation slope was divided into three categories: 0 - 2, 2 - 10 and 10 - 9999. These categories have been used in the SWAT model land use conversion and were also used similar way in the map preparation to maintain forest and agricultural expansion area slopes comparable to the baseline.

10.2.2 Land use

Land use information at the MRC has been developed during two different periods of time with varying detail and quality. MRC land use 2003 has been used in the DSF/SWAT modelling and the 2010 data in the impact modelling and socio-economic analysis. The land use of 2010 is more detailed and higher resolution than the 2003 map. However, in order to maintain compatibility with the SWAT model only 2003 land use data has been used in the map preparation.

There are several errors in the 2003 map that could cause difficulties for running the land use change processing. Most of the inconsistencies found were located in the delta area of Mekong River. The land use with errors and corrected map is shown in the Figure 20. The errors shown in the Figure 20 are common in cases where the polygonal element that covers one specific area is wrongly defined or overlapping with other areas. The polygons that compose the land use 2003 map had to be verified for other areas than Delta but the errors shown in the Figure 20 were the most serious and easy to identify.

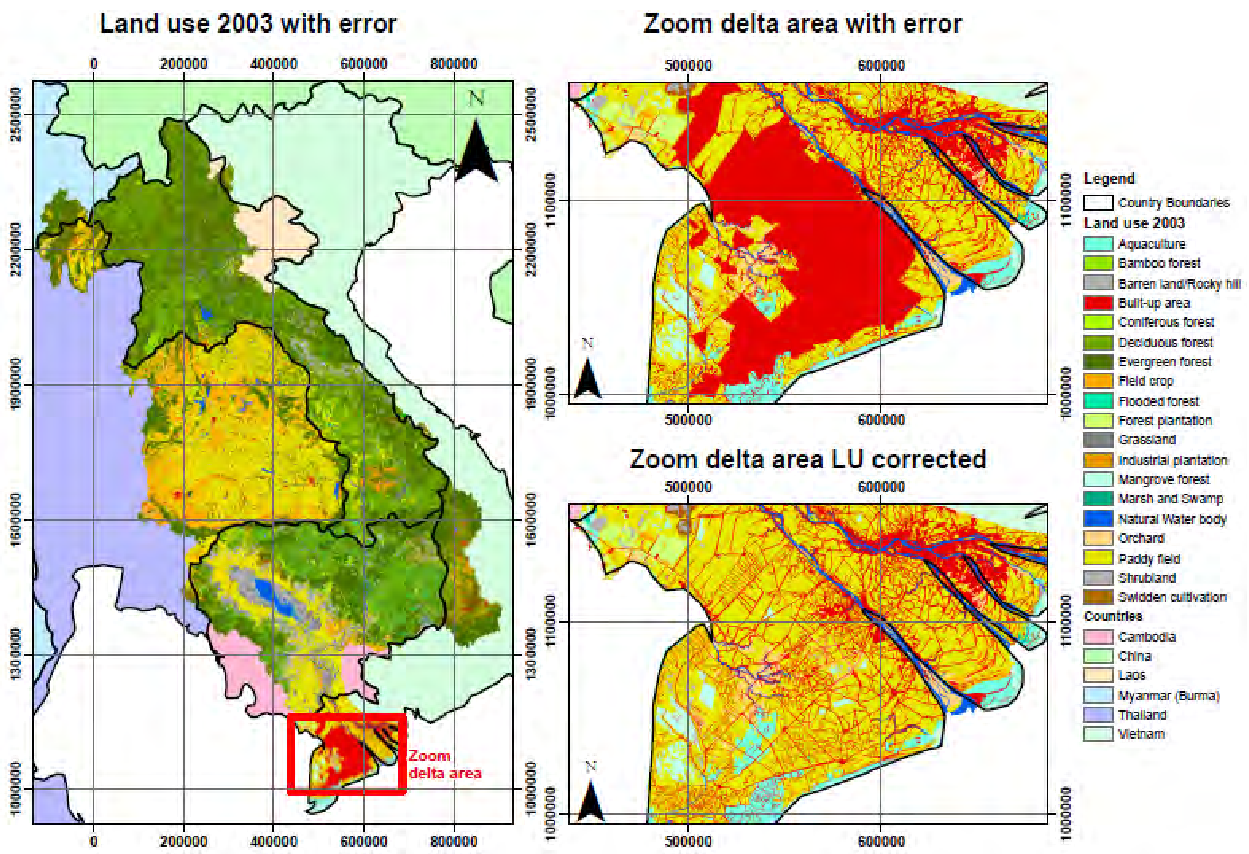


Figure 20. Land use 2003 with errors and zoom area with error and corrected

After correcting the land use, it was possible to identify correctly the different land use types. They are classified from 1 to 19 as shown in Figure 20. They have been reclassified into 7 groups used in the SWAT as shown in the Table 21. The colors in the table represent the group types while the detailed type ID and name present the original classification. The table also shows the area and percentage of each original land use class. The most common types are Evergreen forest, Deciduous forest and Paddy field covering 71.54% of the LMB.

The difference between the original and reclassified land use maps is shown in the Figure 21. Although the majority of areas and especially most representative areas are similar between the maps it is possible to see more details in the original map.

Table 21. Table of land use IDs for detailed and group types.

Group ID	Group name	Detailed ID	Detailed name	Area (km²)	Area share
1	Forest	1	Evergreen forest	186993.19	30.07%
2	Others	2	Grassland	12643.00	2.03%
1	Forest	3	Deciduous forest	132487.77	21.30%
3	Agriculture	4	Swidden cultivation	20394.46	3.28%
3	Agriculture	5	Industrial plantation	4500.92	0.72%
4	Paddy field	6	Paddy field	125458.50	20.17%
5	Water	7	Natural Water body	10271.57	1.65%
2	Others	8	Barren land/Rocky hill	4729.93	0.76%
1	Forest	9	Bamboo forest	8904.78	1.43%
6	Built up area	10	Built up area	9113.16	1.47%
3	Agriculture	11	Orchard	4141.20	0.67%
3	Agriculture	12	Field crop	40241.64	6.47%
7	Wetland	13	Marsh and Swamp	2693.13	0.43%
2	Others	14	Shrubland	18556.89	2.98%
7	Wetland	15	Flooded forest	6729.79	1.08%
7	Wetland	16	Aquaculture	969.45	0.16%
1	Forest	17	Coniferous forest	30292.78	4.87%
1	Forest	18	Forest plantation	2421.65	0.39%
7	Wetland	19	Mangrove forest	402.84	0.06%

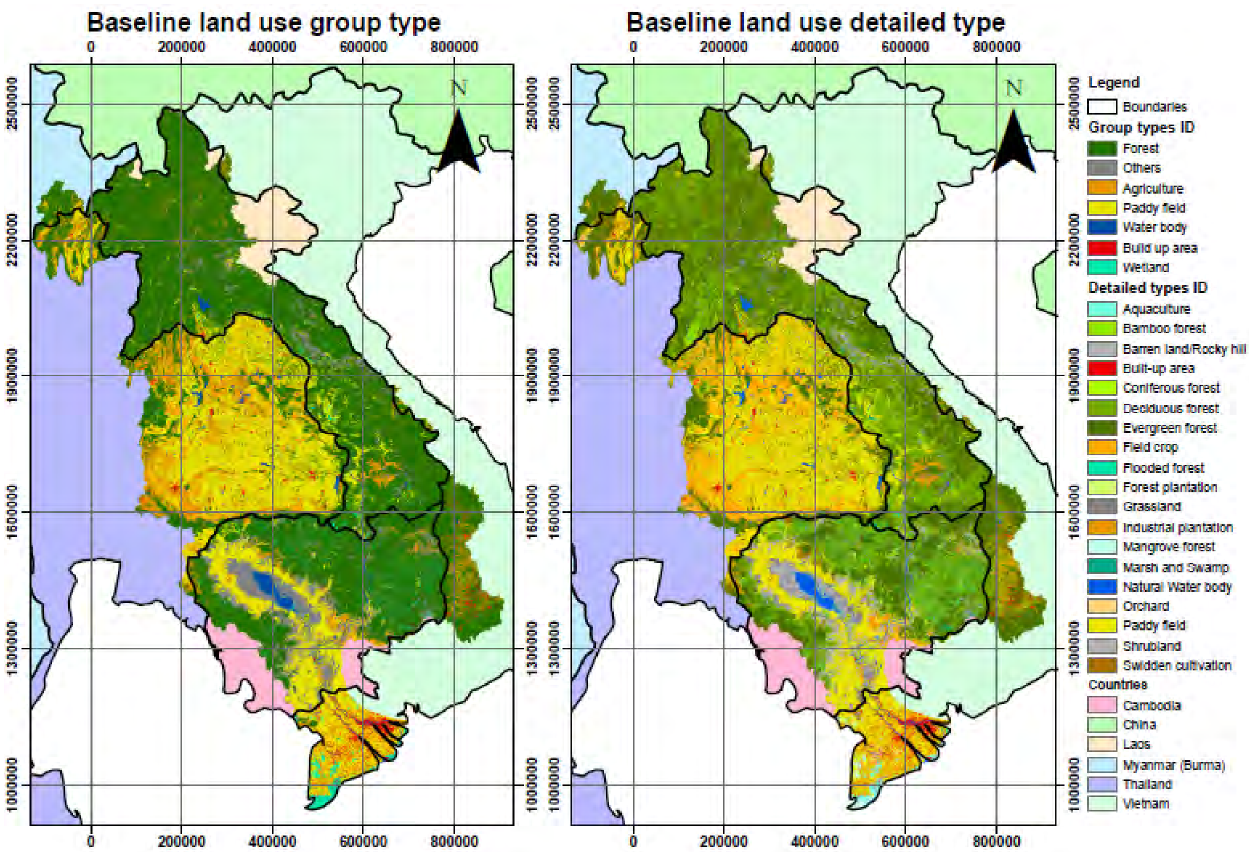


Figure 21. Reclassified land use map (left) compared to the original 2003 map (right).

10.2.3 Sub-basins - regions

The percentage modifications of the land use were established for a sub-basin scale defined according to SWAT model. They were divided into 9 main regions with each region containing between 40 to 150 sub-basins to a total of 662 sub-basins. Swat model doesn't include Cambodian floodplains and Vietnam Delta but if they are included as provincial areas the number of sub-areas to consider is of about 780 polygons.

Several errors in the sub-basin division were found. These include mainly overlapping and not-connected sub-basins and displaced elements. These errors can be caused by errors in information processing as well by use of data from different non-matching sources. Example of the errors is shown in the Figure 22. The figure shows in blue color the location of the areas with errors. The errors have been corrected for consistent map and data processing.

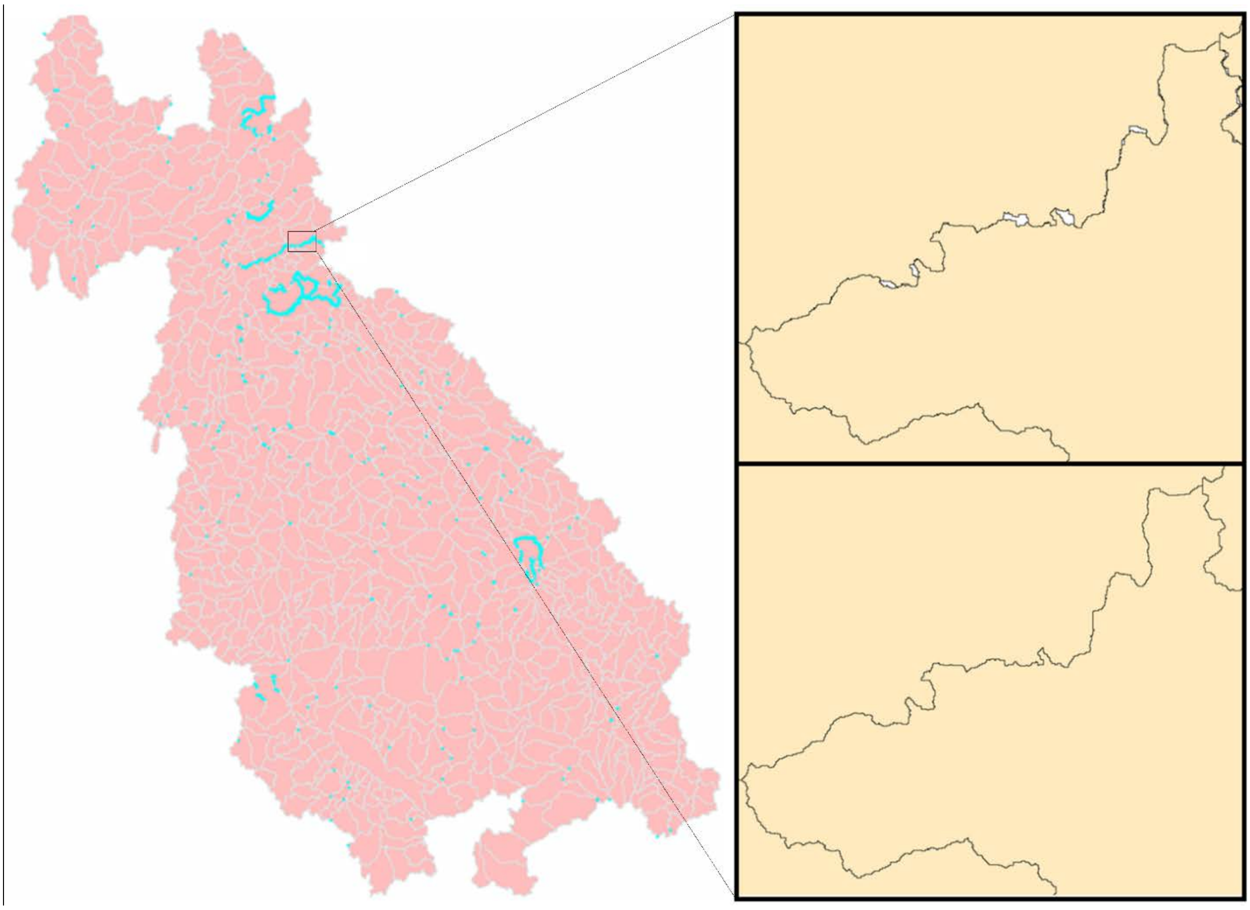


Figure 22. Errors (non-matching polygons) and error correction in the SWAT sub-basin delineation.

The topological errors were corrected by using the ArcInfo Arctool "Union" and "Eliminate". The tool "Union" with option "No holes" fills all the holes and overlapping elements while the tool "Eliminate" merges the newly created elements with the nearby elements to form a new map with no topological errors.

10.2.4 Land use classification

The land use of 2003 was modified according to land use change developed for the SWAT hydrological model. The percentage of change was categorized by slope, soil type and land use type. Three maps were developed for the 2020 and 2040 main scenarios and 2040 HIGH sub-scenario.

Data processing, or land use change modeling, was divided into four parts consisting of common changes between the scenarios and differences in the 2020, 2040 and 2040 HIGH scenarios (Figure 23).

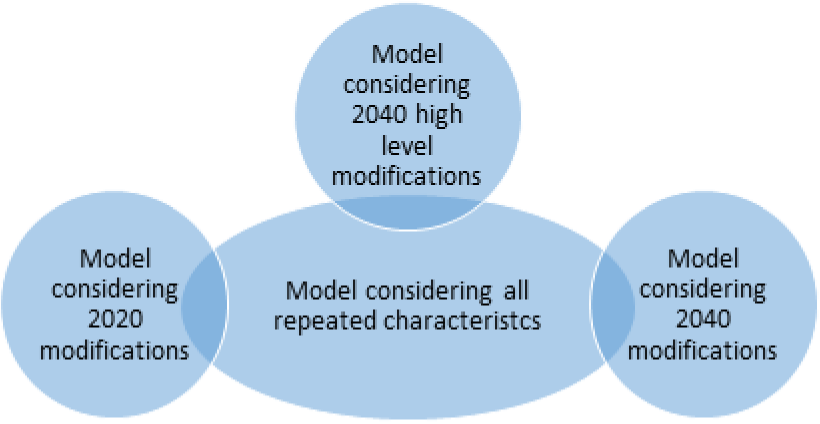


Figure 23. Schematization of the land use change modeling

Although the SWAT land use classification doesn't correspond directly to the MRC 2003 land cover classification it was possible to correlate the two classification systems (Table 22).

Table 22. Land use classfication on SWAT (first column) correlated with the 2003 land use map (second column)

Group type ID	Land Use map ID	Land Use map name	SWAT Code	Land cover name in SWAT
1	1	Evergreen forest	EMLD	Evergreen, medium-low cover den
1	1	Evergreen forest	FRSL	LMB Forest land
1	3	Deciduous forest	DECD	Deciduous
1	3	Deciduous forest	DTFR	LMB Disturbed forest land
1	3	Deciduous forest	MEDM	Mixed(evg&dec)med-low cover de
1	3	Deciduous forest	WSDR	Wood- and shrubland, dry
1	3	Deciduous forest	WSEV	Wood- and shrubland, evergreen
3	4	Swidden cultivation	SWIN	Wood- and shrubland, inundated
3	12	Field crop	FCRP	LMB Field crop
4	6	Paddy field	PDDY	LMB Paddy field
5	7	Natural Water body	WATR	Water
6	10	Built up area	URBN	Urban or built-over area
7	13	Marsh and Swamp	WETD	Wetland

It can be observed in the Table 22 that one 2003 land use map ID can have more than one SWAT land cover code. The re-grouping follows

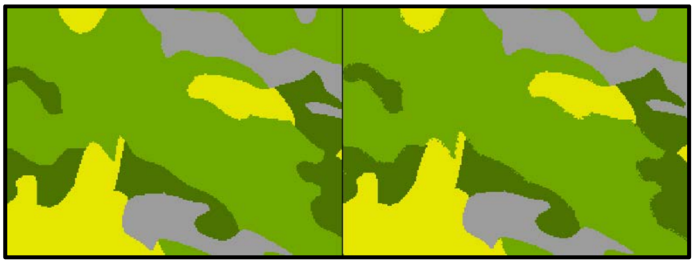
Table 21. This creates difficulties for the land use change modelling and map preparation for identification of the correct land use to be modified, although in most cases the land use is consistent to the land use ID 2003. Also land use class properties can vary between the two data sets affecting the calculation.

In general grouping of land use types is not an ideal solution for data harmonization between SWAT and 2003 land use map data. For instance in the 2003 map deciduous forest (class 3) and evergreen forest (class 1) change need to be separated but under SWAT there is only one forest class.

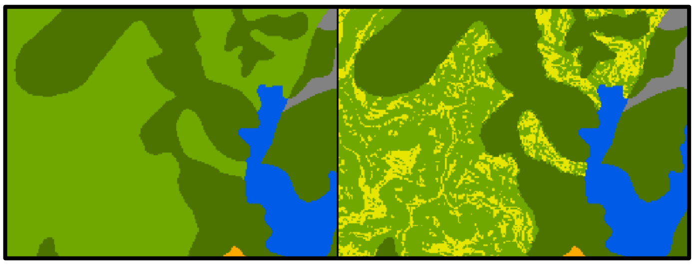
10.2.5 Change criteria

The land use change model requires to recognize two land use types, the land use that is expected to disappear and the land use that is expected to take its place. After recognizing the amount of those land uses and their locations, it requires the percentage of change expected and the condition of slope where that change is expected to happen. If any of those criteria is not filled then the change is not applied. The three conditions for the change are:

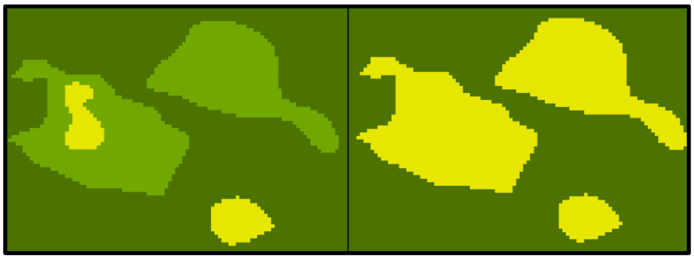
Proximity: It is defined by the land use that is expected to change and the land use that is replacing it. The condition looks for both land uses slope criteria to modify the cells that are closer to the condition. For this condition to be applied, the new land use expected needs to be more than 0.5% of the total land use of the sub-basin.



Slope Fill: This case considers only the slope as criteria to fill the sub-basin until the total percentage of change is reached. It only changes the cells were the land use is supposed to change to the new land use and it is only active when the new land use expected covers less than 0.5% of the total area of the sub-basin.



Filling: Finally, the filling criteria seeks to optimize the processing time of big areas with major changes. It is actived when the area that is changing is more than 95% of the total area expected to change. It means that all or almost all the area is expected to change so it just fills the value replacing the old land use to the new land use.



Both Proximity and Slope Fill work complementarily. In cases in which the total amount of change is not fulfilled for the proximity condition but there is still area remaining to be change according to the percentage condition, then the condition is changed automatically to slope filling to continue the filling until the percentage is completed. In the three cases, if the expected percentage of change is not reached and there are not more cells that fulfill the criteria, the model stops and gives the map as the resulting map. Otherwise it will continue until reaching the maximum percentage of change expected and creates finally the modified map.

10.3 Impact modelling methodology

The methodology to implement landuse change in the MRC DSF modelling is:

1. Define potential area for forest and agriculture land change based on year 2003 and year 2010 landuse.
2. Assume the changing area of forest and agriculture are around the existing landuse areas
3. Apply rate of change from each country into SWAT sub basins and HRUs
4. Apply values in the model
5. Compute changes in flow, sediments and nutrients.

The socio-economic assessment including food security, household income and macro-economic analysis require assessment of crop production for the future scenarios. The physiological FAO AquaCrop model (Figure 24) has been used for computing crop yields in the future scenarios. The AquaCrop model is integrated in the distributed IWRM hydrological model. The land use information for the AquaCrop modelling is based on the MRC 2010 land cover map supplemented with the BDP2 irrigation area data.

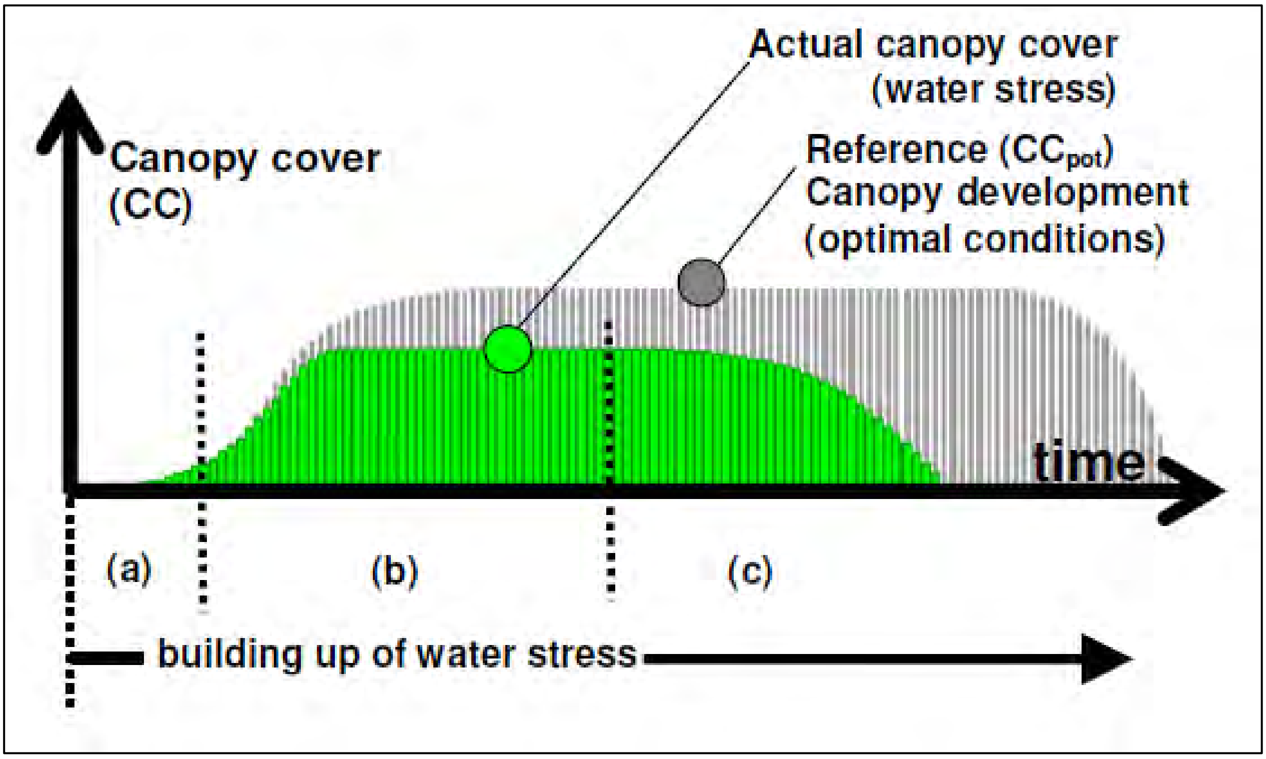


Figure 24. AquaCrop model plant growth representation

10.4 Use of the SWAT model as basis of the assessment and baseline conditions

The hydrological model SWAT has a central role in assessing land use change impacts as it computes change impacts on flow, sediments and nutrients. In this chapter the SWAT model results for the baseline are presented and evaluated.

Figure 25 shows lower Mekong basin average annual precipitation interpolated by the DSF and IWRM models. The DSF data has been gap filled and interpolated from measurements using the MQUAD algorithm. The IWRM data has been interpolated using orographic correction using observation station data. To a large extent the rainfall maps are similar to each other showing largest rainfall in the Eastern part of the basin and driest conditions in the Chi-Mun basin.

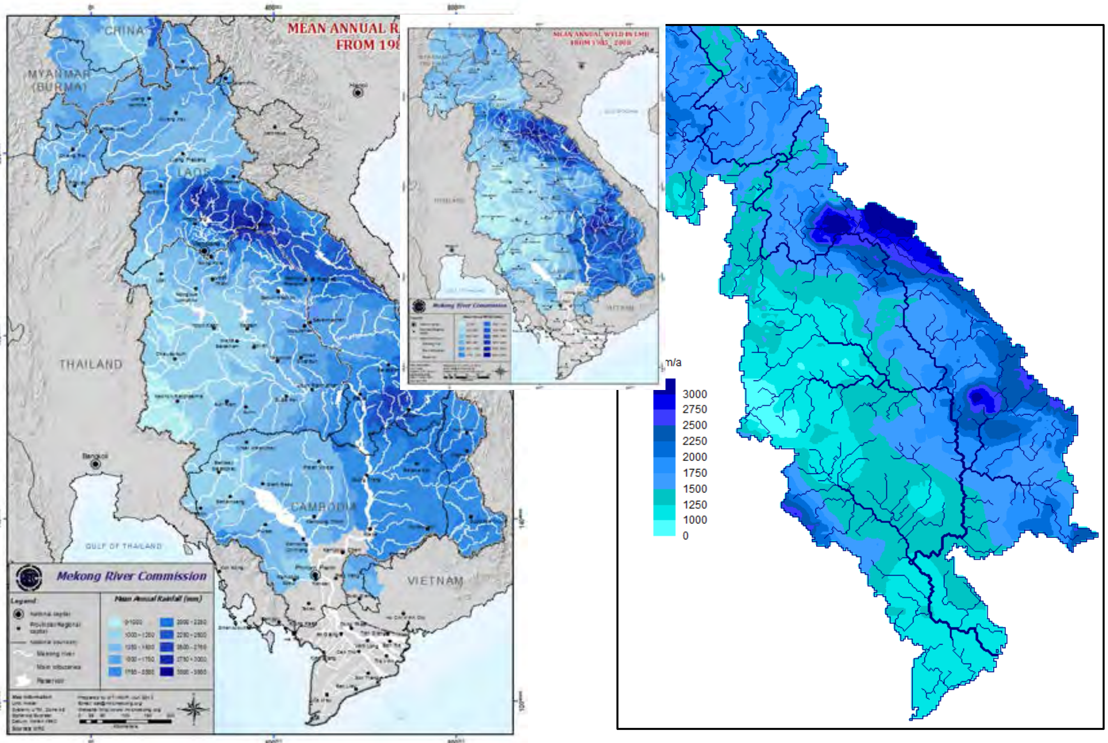


Figure 25. Average annual precipitation. Left precipitation used in SWAT and right IWRM interpolated precipitation. Small figure shows SWAT computed annual water yield. (SWAT figures ref. SWAT Modelling Report)

Figure 26 shows annual average erosion computed with the SWAT and IWRM-models. There is large discrepancy between the models both in erosion amounts and areas. The erosion amounts in the SWAT model seem to be order of magnitude smaller than in the IWRM-model. The distribution corresponds very roughly in large scale but specific erosion areas don't seem to correspond to each other too much. In the large scale high erosion corresponds to high precipitation and mountains whereas low and flat areas have quite low erosion rates.

It would be important to clarify the discrepancy between the models. At the moment it is difficult to see the reason for the discrepancy, but the IWRM-model seems to be consistent with the measured loads in the baseline (pre-development) conditions:

- Average computed annual discharge in Stung Treng is exactly same as the measured one.
- R2 of the measured and computed daily discharge is 0.92 in Stung Treng
- 86 Mt annual sediment load at the Chiang Saen station correspond to the estimated loads based on the monitoring data
- 160 Mt annual sediment load at Kratie corresponds to the estimated loads based on the monitoring data.

SWAT nutrient loads (Figure 27) have similar but not identical pattern as the sediment loads. The computed loads seem to depend on terrain slope and precipitation and not so much on land use such as agriculture. As a matter of fact very little of nutrients originate from the large agricultural areas in Thailand.

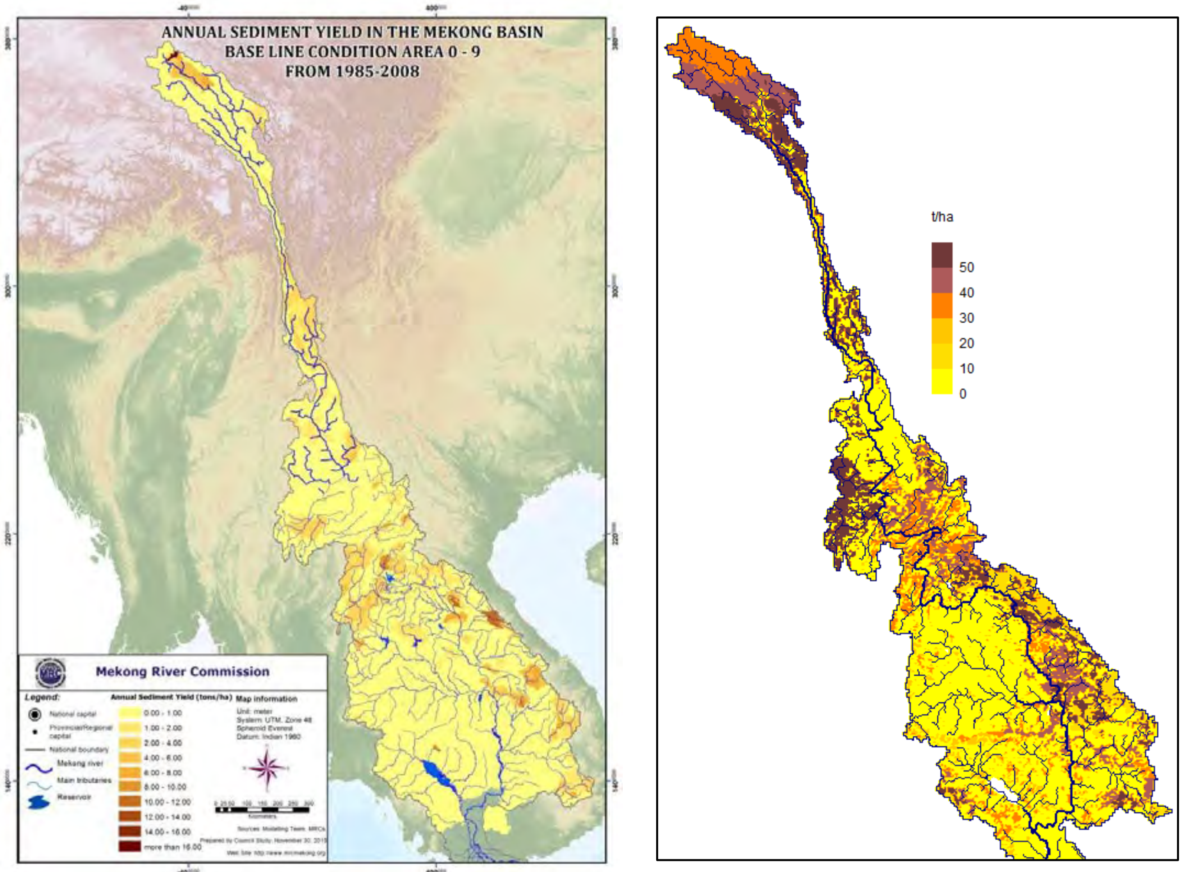


Figure 26. Average annual erosion. Left SWAT, right IWRM-model. (SWAT figure ref. SWAT Modelling Report)

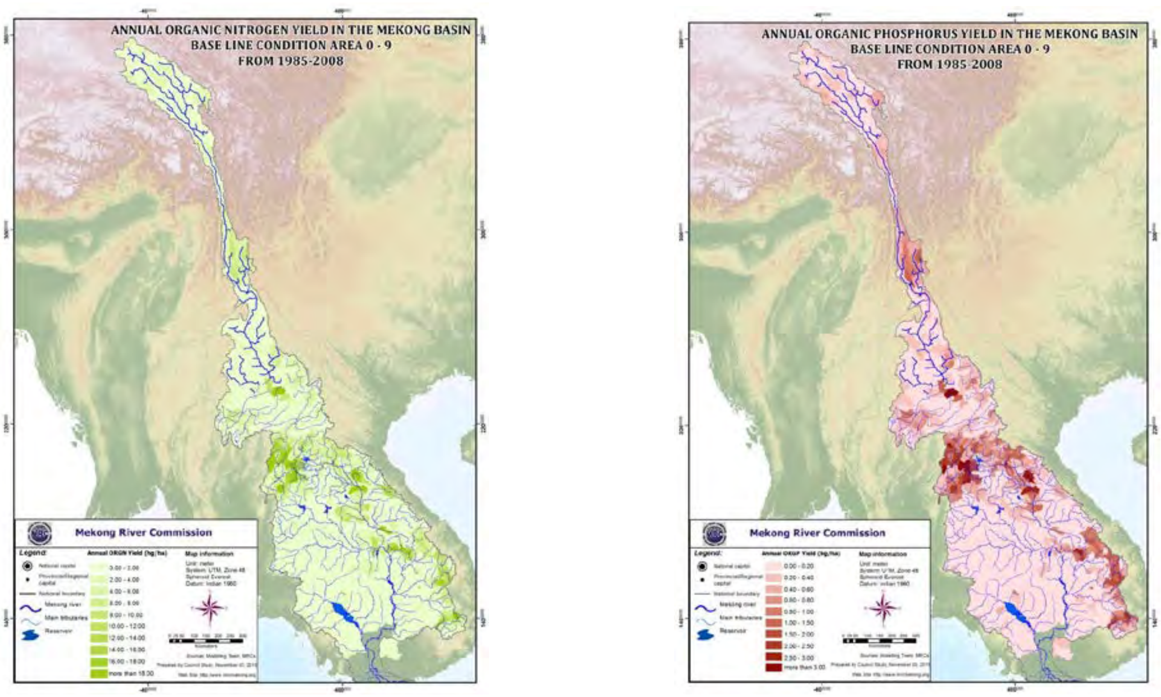


Figure 27. SWAT computed nutrient loads. Left nitrogen and right phosphorus. (ref. SWAT Modelling Report)

11 Land use changes in 2020 and 2040 compared to the 2007 baseline

The land use change modelling used altogether 461 conditions. 186 of them were for the 2020 and 2040 scenarios and 52 for the 2040 HIGH scenario. 37 conditions were common for all of the scenarios. Figure 28 and Figure 29 show the resulting maps for the baseline, 2020, 2040 and 2040 HIGH. It is not easy to identify the changes under the scale of information presented in these maps with the exception of the middle part of the basin where deciduous forest is changing to paddy field in the upper part of Tonle Sap Basin.

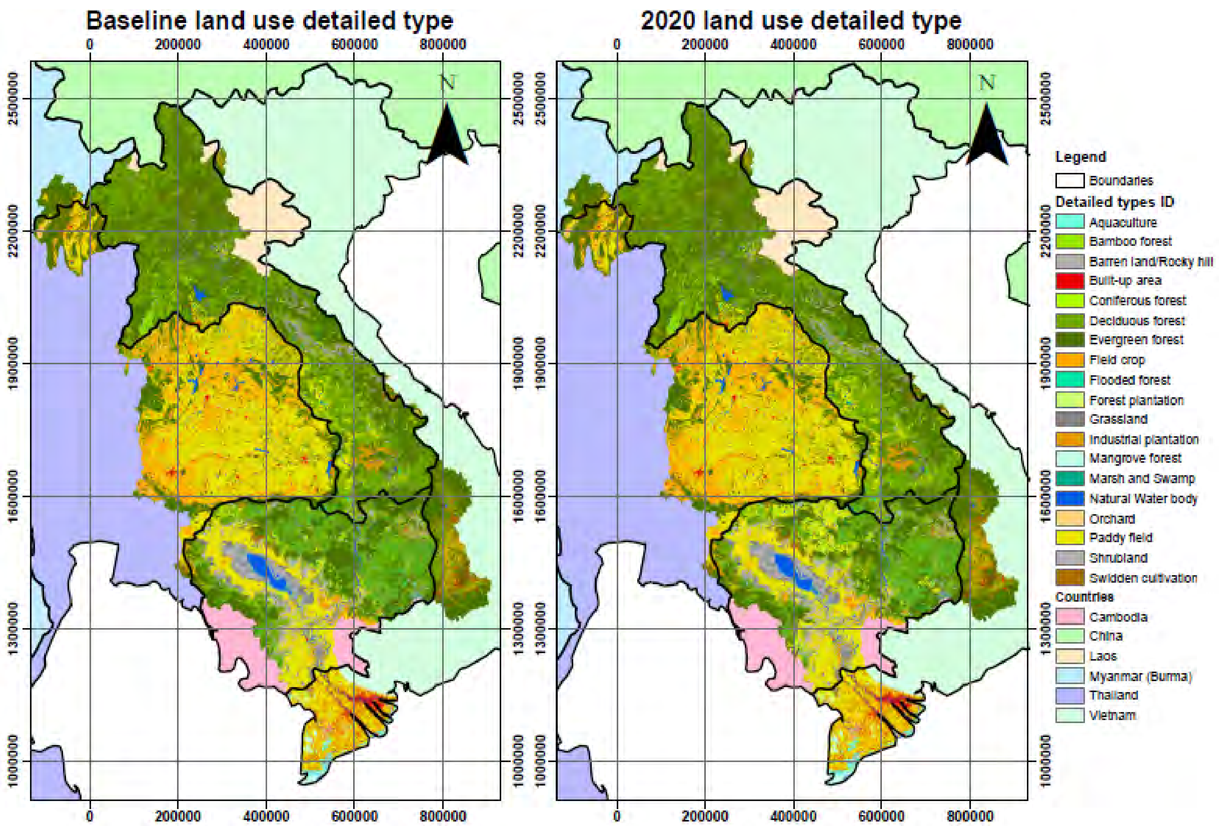


Figure 28. Baseline and 2020 land use detailed classification

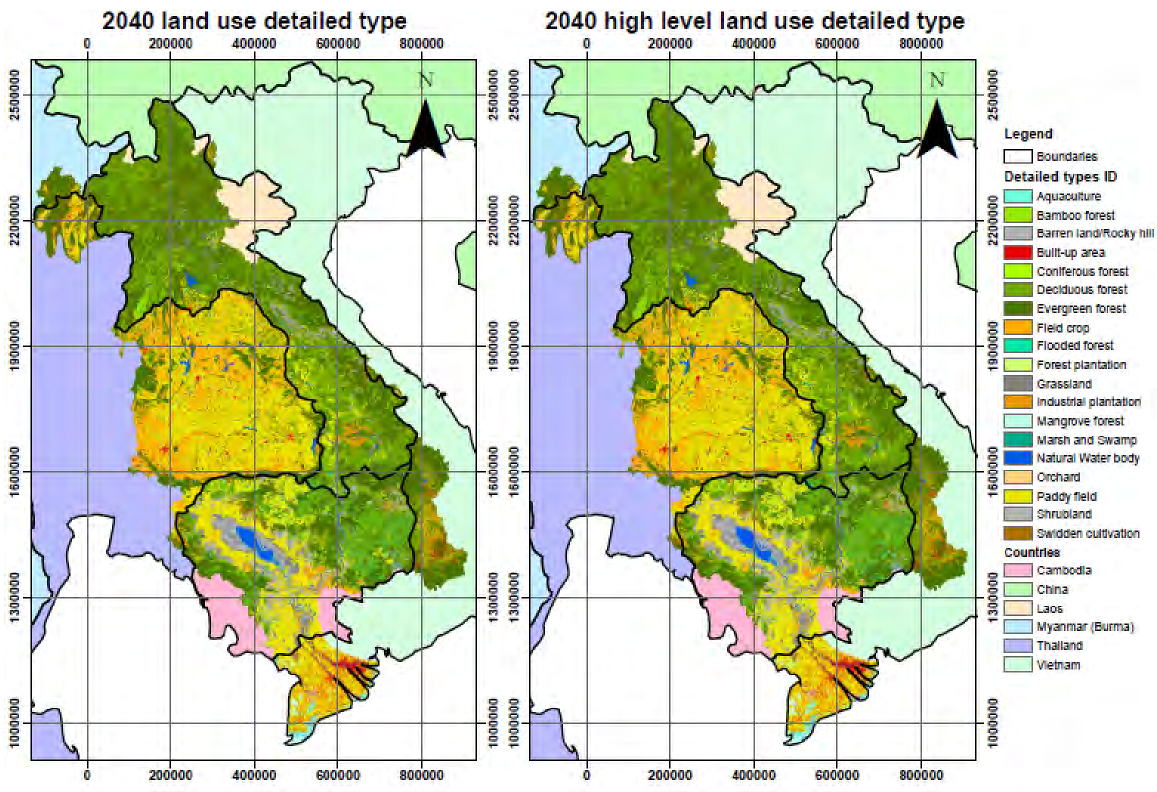


Figure 29. 2040 and 2040 HIGH land use detailed classification

In order to check land use modelling results three SWAT sub-basins, 18A2, 1A9 and 26A5, have been selected for analysis (Figure 30).

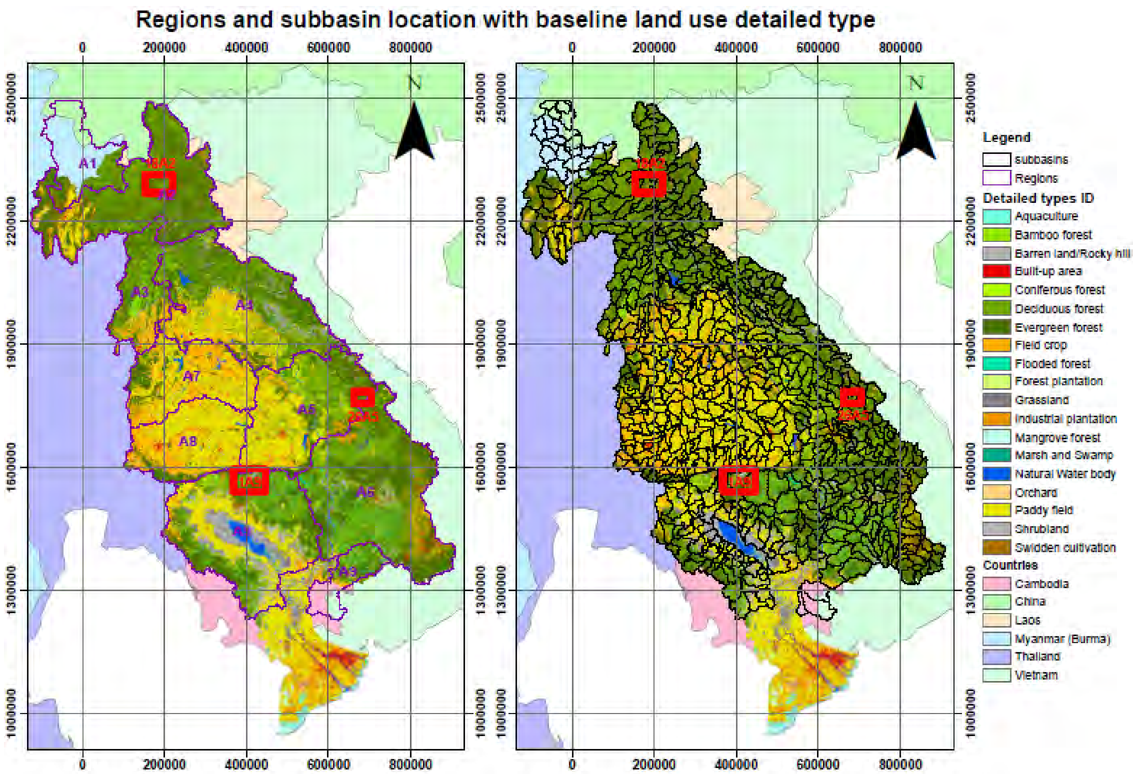


Figure 30. Location of the 18A2, 1A9 and 26A5 SWAT sub-basins. SWAT sub-basin boundaries shown on the right.

The sub-basin 18A2 land use changed for 2020 and 2040, while it was not changed for 2040 HIGH. The types changing are deciduous forest to paddy field and forest land. Due to the low percentage of change it is nearly impossible to see differences between the scenarios (Figure 31 and Figure 32). In the scenarios forest with slope 2 – 10 change 3.3% for 2020 and 7.3% for 2040 compared to the baseline. Paddy field with slope 0 – 2 changes 1.5% for 2020 and 2.4% for 2040 compared to the baseline:

basin	scenario	search	new	0-2	2-10	10-9999	search	new	0-2	2-10	10-9999
18A2	2020	3 DECD	1 FRSL	0.00%	3.29%	0.00%	3 DECD	6 Paddy field	0.00%	1.45%	0.00%
18A2	2040	3 DECD	1 FRSL	0.00%	7.29%	0.00%	3 DECD	6 Paddy field	0.00%	2.40%	0.00%

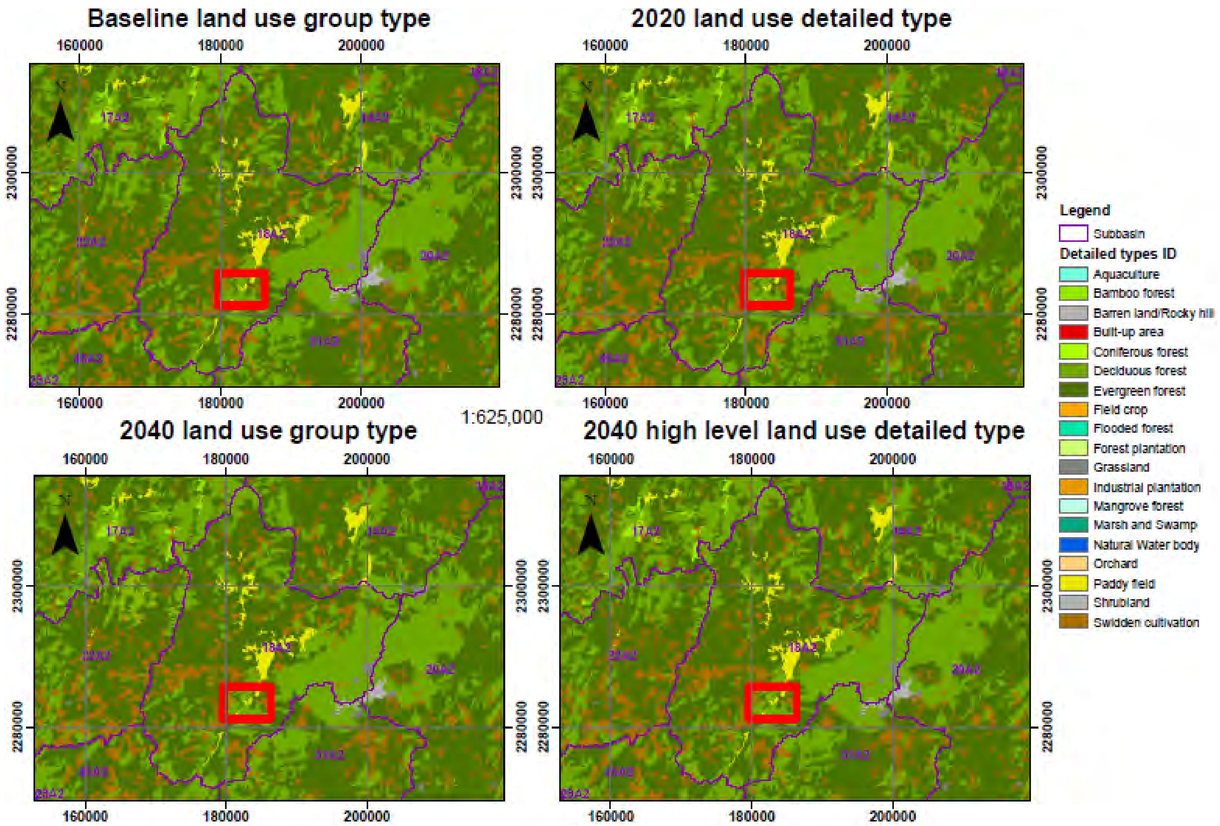


Figure 31. Scenario land use in the proximity of the sub-basin 18A2

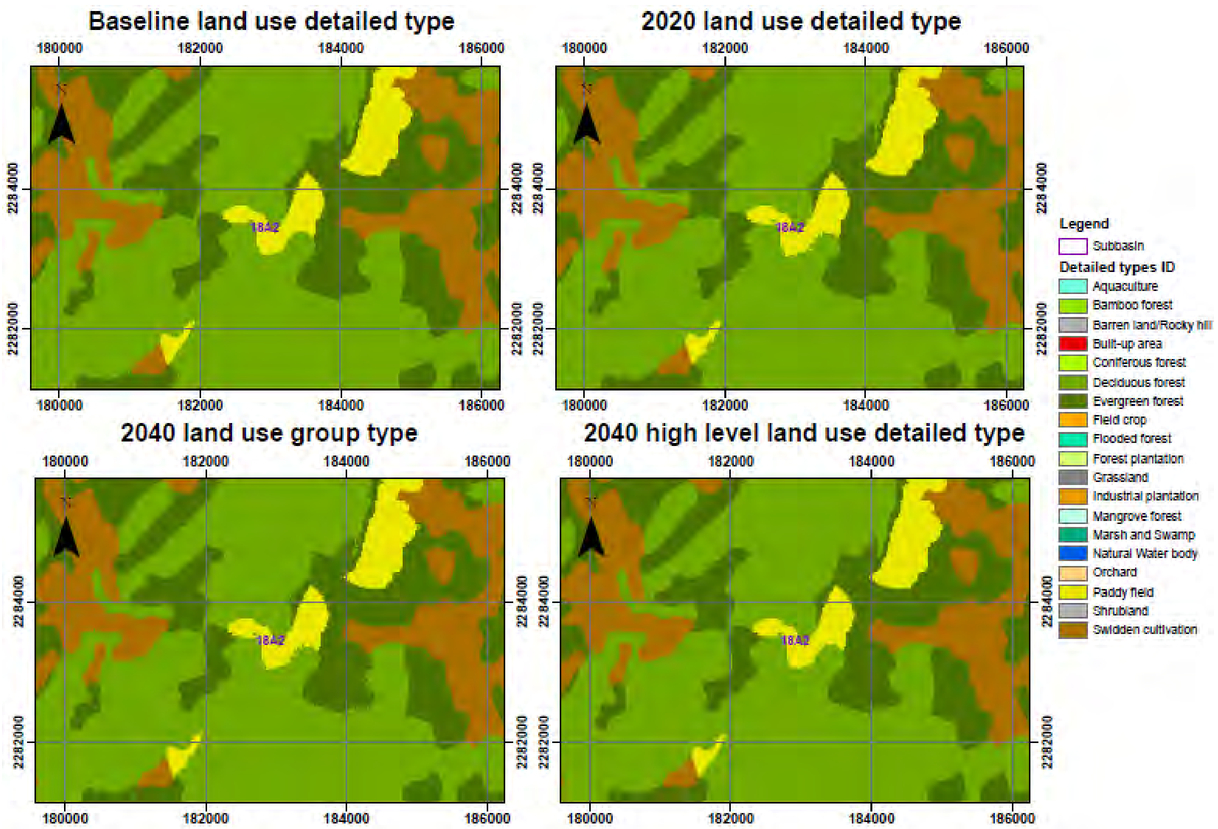


Figure 32. Scenario land use in the sub-basin 18A2

The sub-basin 1A9 change is same for the 2020, 2040 and 2040 HIGH scenarios. The change is from deciduous forest to paddy field. The resulting maps are shown in the Figure 33. 75% of deciduous forest with slope 0 -2 is modified into paddy field:

basin	scenario	search	new	0-2	2-10	10-9999
1A9	2020-2040-2040hl	3 DECD	6 Paddy field	74.93%	0.00%	0.00%

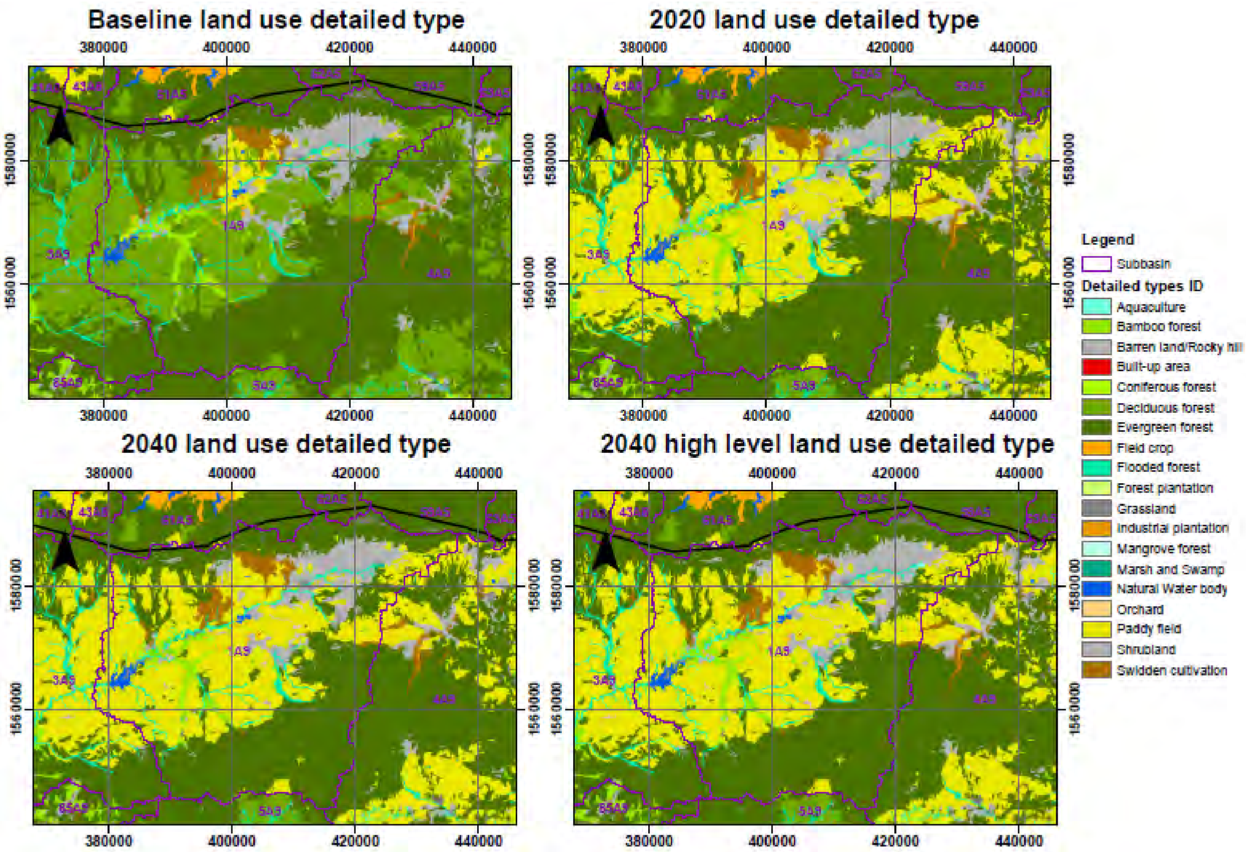


Figure 33 Sub-basin 1A9 land use change for the scenarios

The sub-basin 26A5 changes are different for the different scenarios:

basin	scenario	search	new	0-2	2-10	10-9999	search	new	0-2	2-10	10-9999
26A5	2020	3 DECD	1 FRSL	0.00%	7.73%	0.00%	3 DECD	6 Paddy field	0.00%	3.41%	0.00%
26A5	2040	3 DECD	1 FRSL	0.00%	17.11%	0.00%	3 DECD	6 Paddy field	0.00%	5.64%	0.00%
26A5	2040hl	3 DECD	1 FRSL	0.00%	17.11%	0.00%	3 DECD	6 Paddy field	0.00%	5.64%	0.00%

The case of 26A5 is an example where the area did not have any paddy field in the baseline. This means that there is no condition to develop proximity so that paddy field is filled according to the slope condition. In contrast the change from deciduous forest to evergreen forest was implemented according to proximity. Figure 34 shows the changes.

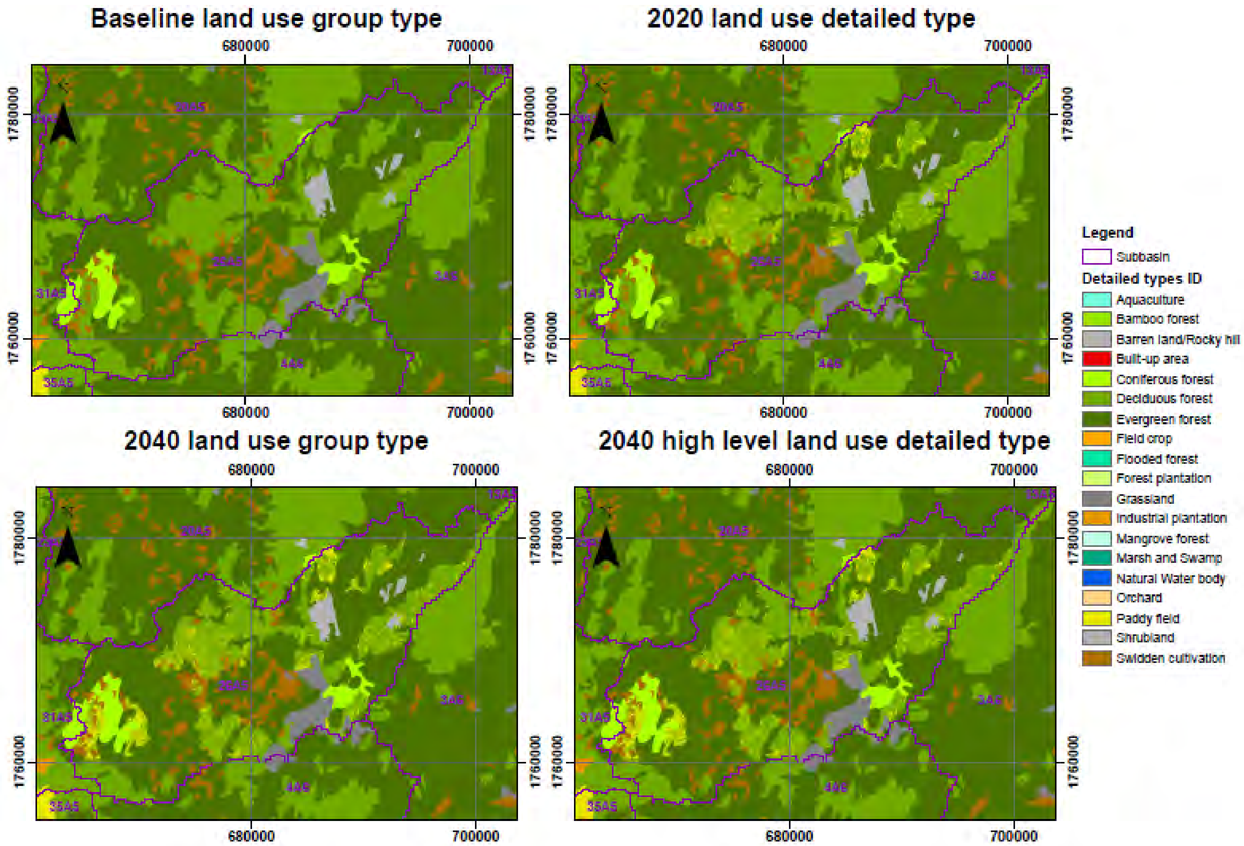


Figure 34 Sub-basin 26A9 land use change for the scenarios

Total land use change in the LMB is shown in Figure 35. The total areas are shown as bars and percentage change as line.

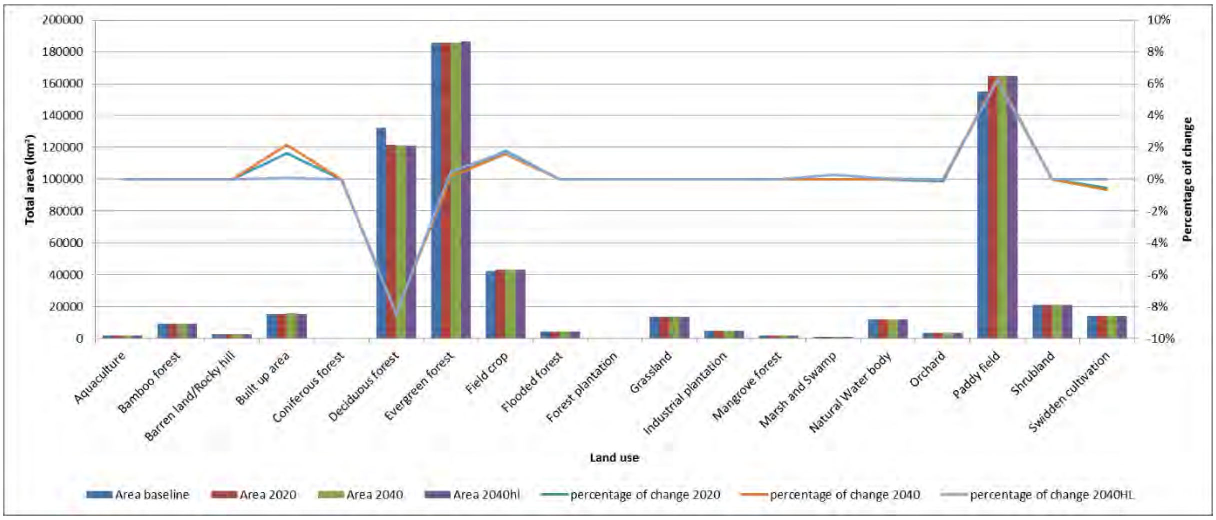


Figure 35. Land use area (bars) and percentage of change (line) for each land use type in the LMB

Majority of changes involve built up areas, deciduous forest, field crop and paddy field. For the future scenarios the major loss of land is happening within areas with deciduous forest type while the major increase is over built up area and paddy field, with paddy field changing in a bigger proportion of the change in the total area. Figure 36 shows the same information as Figure 35 although applied to the land use group types which combined most of the general conditions. Forest shows the highest decrease while paddy field shows the highest increase both in total area and proportionally. Built up areas show also high increase but their proportion is small of the total area.

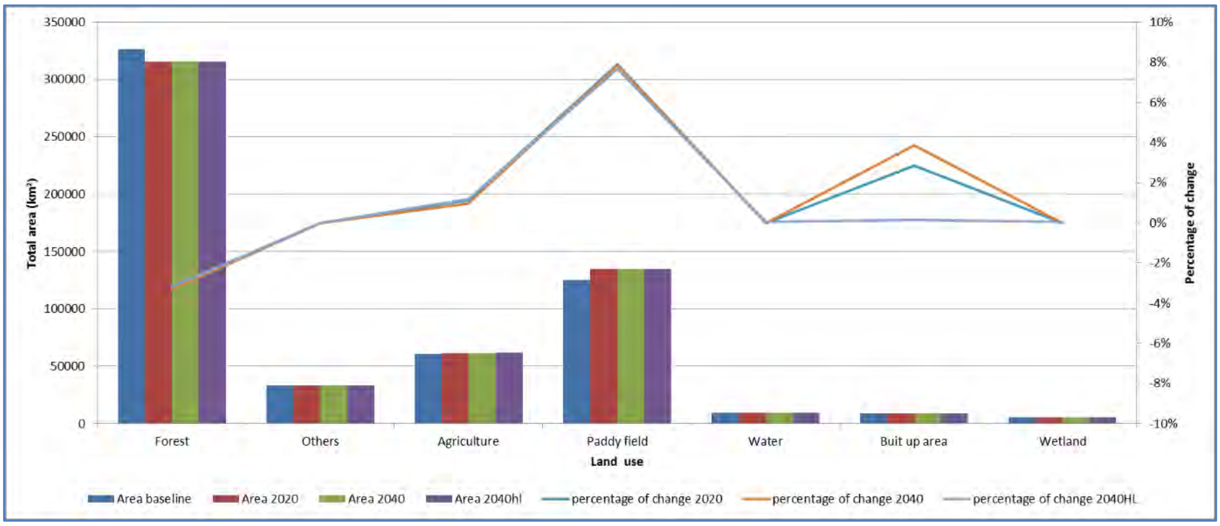


Figure 36 Land use area and percentage of change for each land use group type

12 Agriculture and land use impacts on flow and sediments

12.1 Agriculture scenarios

MRC DSF model has been used to analyze impacts of the agriculture sub-scenarios A1 (2007 agriculture area) and A2 (high agriculture development). Scenarios A1 and A2 are compared with the M3CC scenario that has other characteristics than the agriculture area identical to the A1 and A2 scenarios.

Figure 37 shows wet season flow changes in different Mekong mainstream locations and Figure 38 dry season ones. The changes are very small, well in the range of model and data errors.

Figure 39 shows average monthly sediment concentrations for the M3CC, A1 and A2 scenarios as obtained from the ISIS model for Kratie. Also, the concentration changes and consequently sediment load changes are insignificant.

Nutrients have not been discussed here as sediments can be taken indicative for nutrient changes. Large part of nutrients is attached to especially to the fine sediment fractions (clay). Also, nutrient simulation can't be yet considered to be reliable.

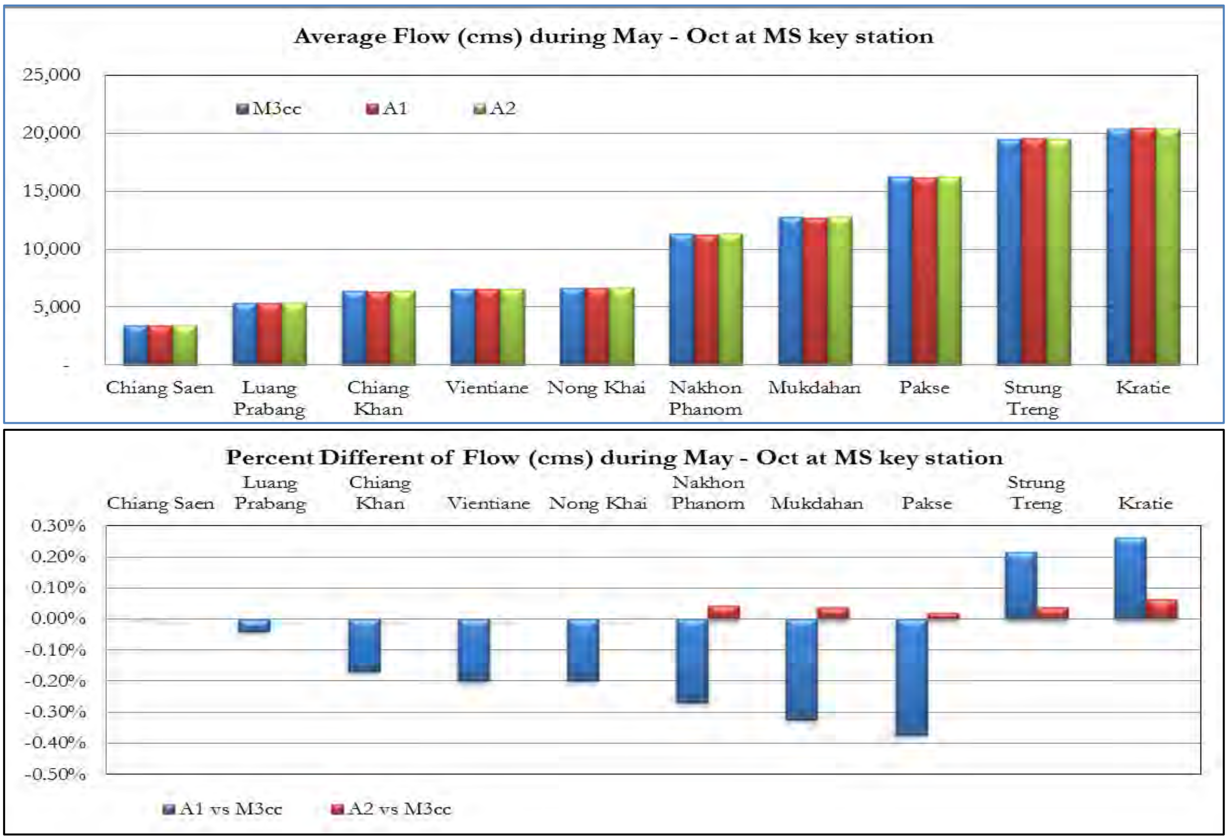


Figure 37 Wet season flow in different Mekong mainstream locations in M3CC, A1 and A2 scenarios. Ref. The IQQM Model for the Council Study Main and Sub Scenarios

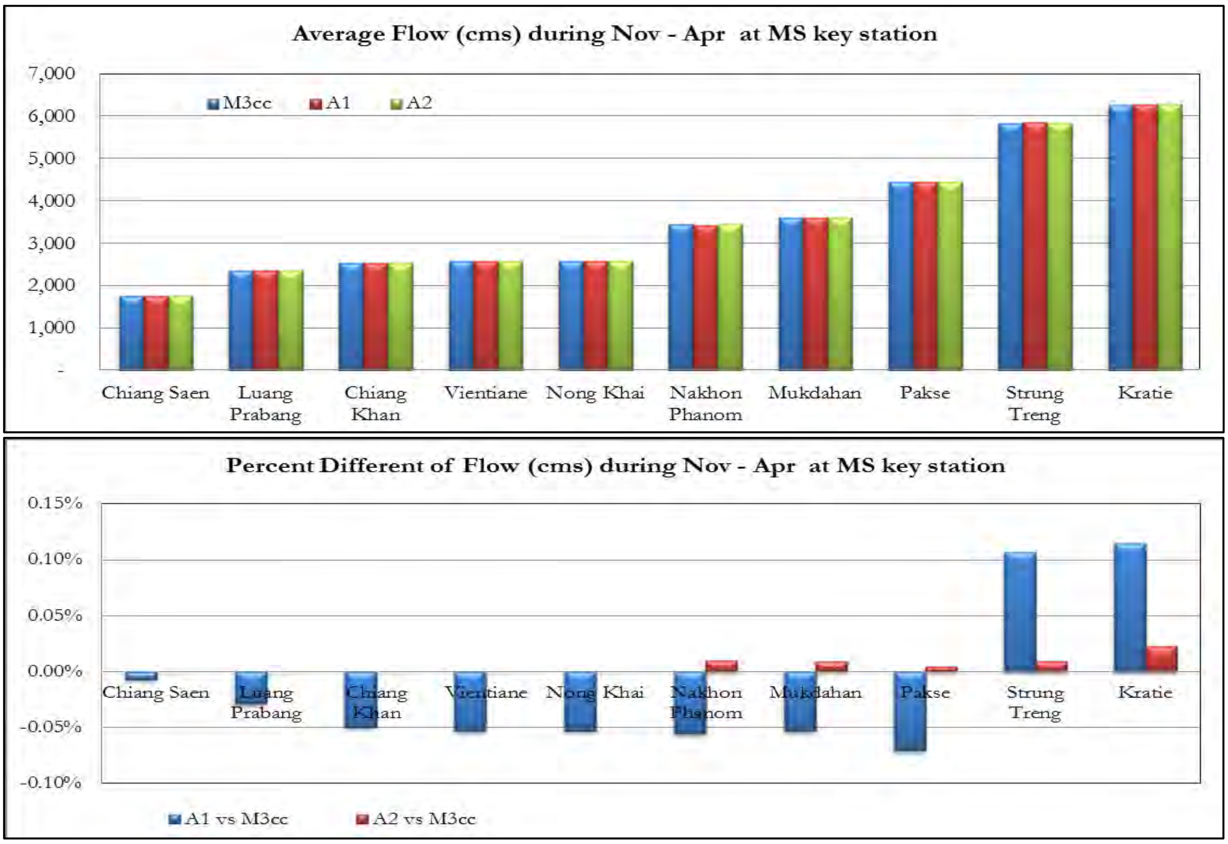


Figure 38 Dry season flow in different Mekong mainstream locations in M3CC, A1 and A2 scenarios. (Ref. The IQQM Model for the Council Study Main and Sub Scenarios)

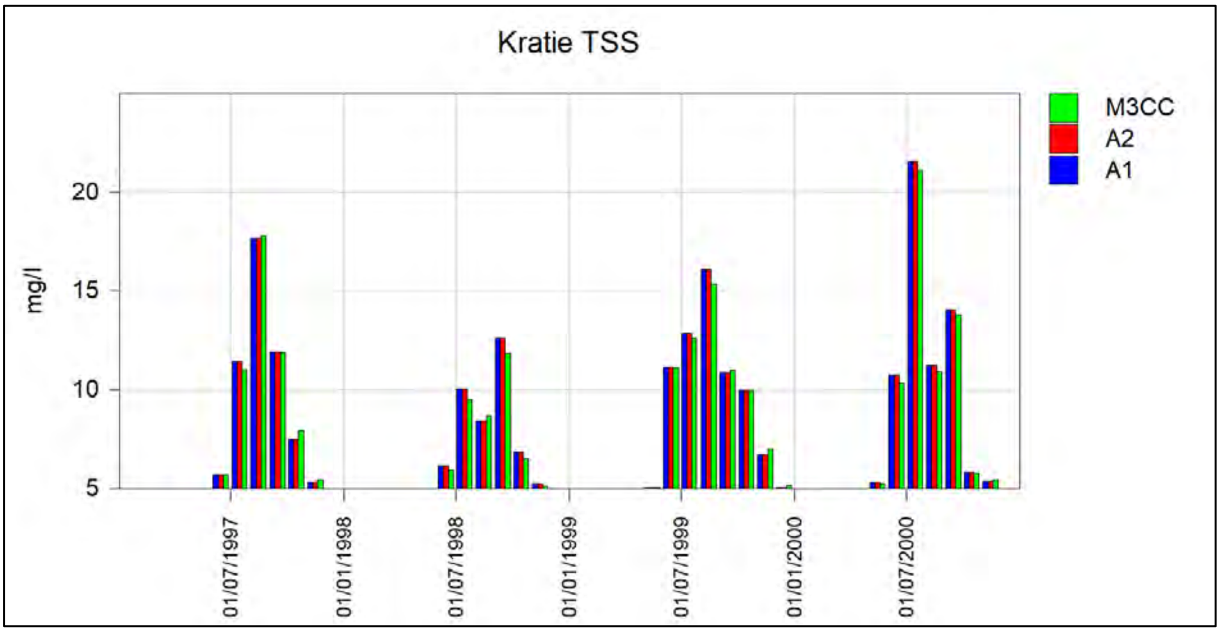


Figure 39 Kratie monthly average TSS (Total Suspended Solids) concentrations in M3CC, A1 and A2 scenarios.

12.2 Deforestation and reforestation (Supplementary section)

Deforestation is not included in the current Council Study scenarios. As it has potentially large impact on Mekong system, indicative modelling results are provided here to illustrate deforestation effects on flow and sedimentation. The land use information, deforestation and modelling results are from the USAID 2012 project Mekong Adaptation and Resilience to Climate Change (Mekong ARCC).

Figure 40 presents model (IWRM/WUP-FIN) land use for the baseline and deforestation. The corresponding annual erosion rates are shown in Figure 41 and Kratie annual sediment loads in Figure 42. The deforestation increases sediment loads 40% compared to the baseline.

Deforestation impacts on flow have been studied at the MRC. The conclusion seems to be that its impacts can't be perceived from the existing monitoring data (Christoph Feldkötter, personal communication). The modelling results support also this as the flow impacts are rather small (Figure 43). The main impact is that deforestation increases highest flood peaks slightly and decreases flows after them. This is because deforestation decreases water absorption by the soil and water is routed to the rivers faster.

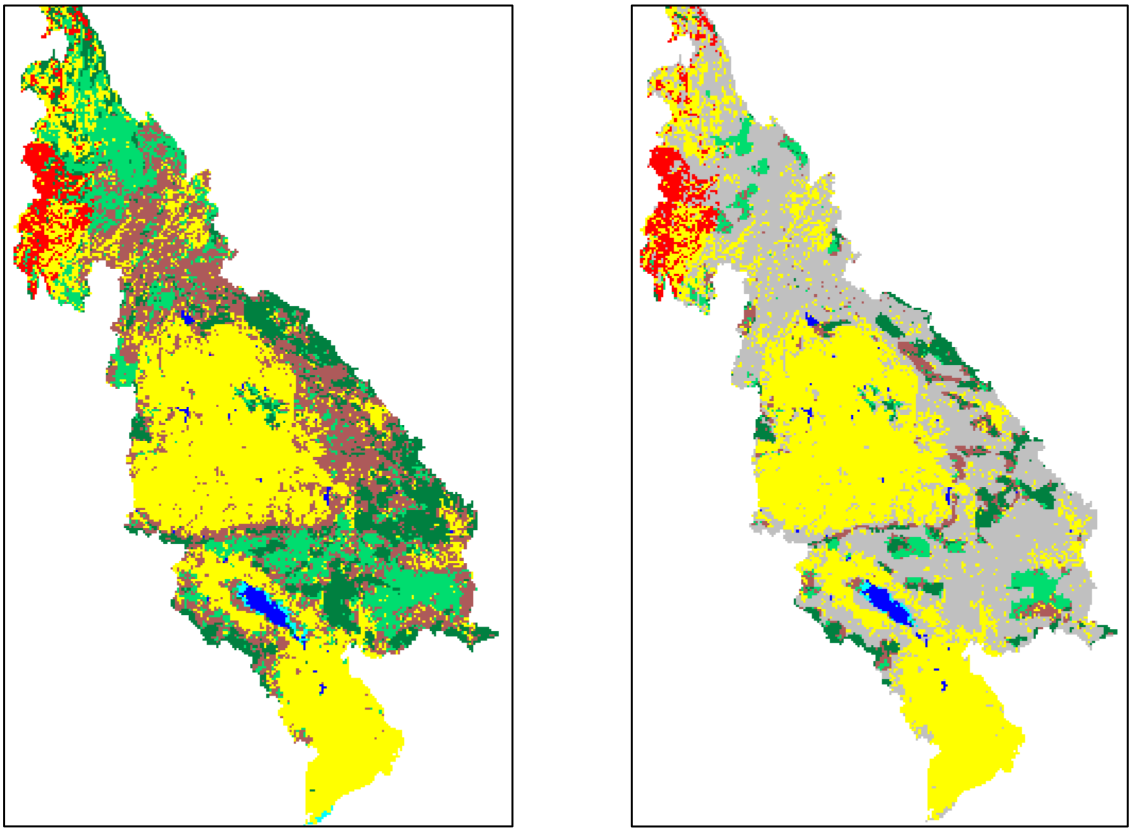


Figure 40 Baseline land use (left) compared to the deforestation one (right). Yellow agriculture and grey deforested and degraded. Land uses from the Mekong ARCC-project (ref. USAID 2012)

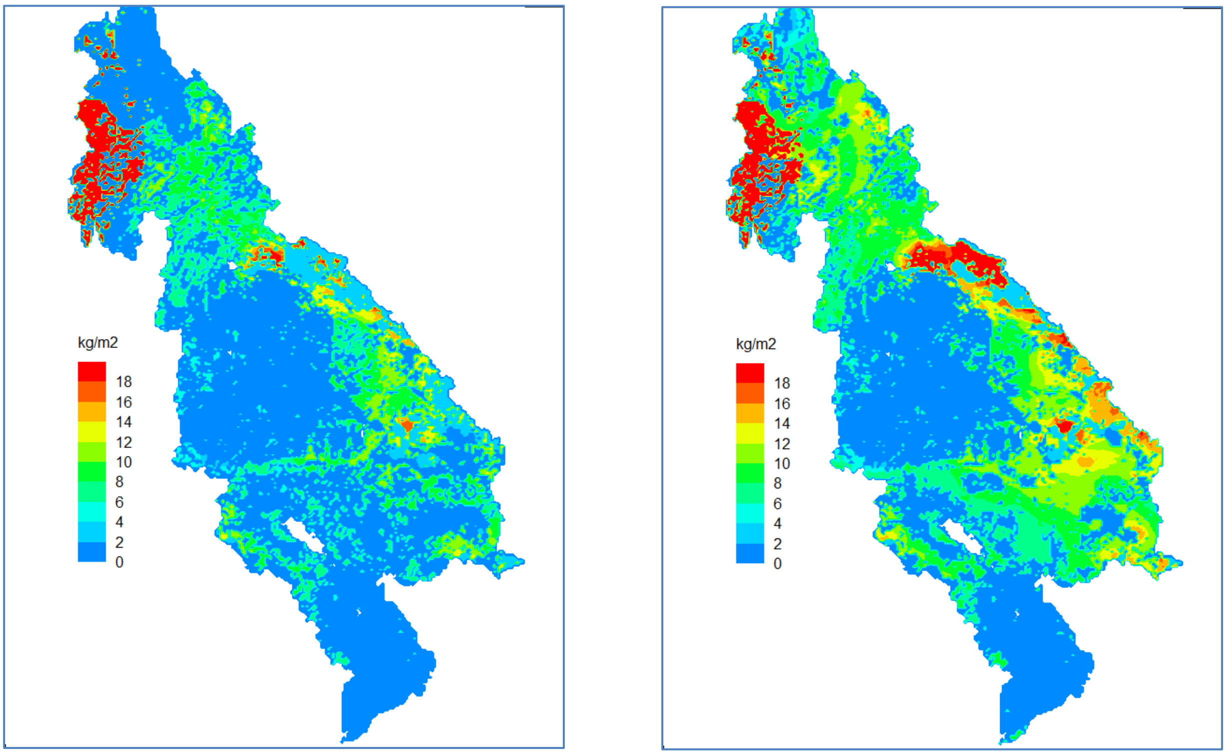


Figure 41 Annual erosion in baseline (BL) and deforestation scenarios. Land uses from the Mekong ARCC-project (ref. USAID 2012)

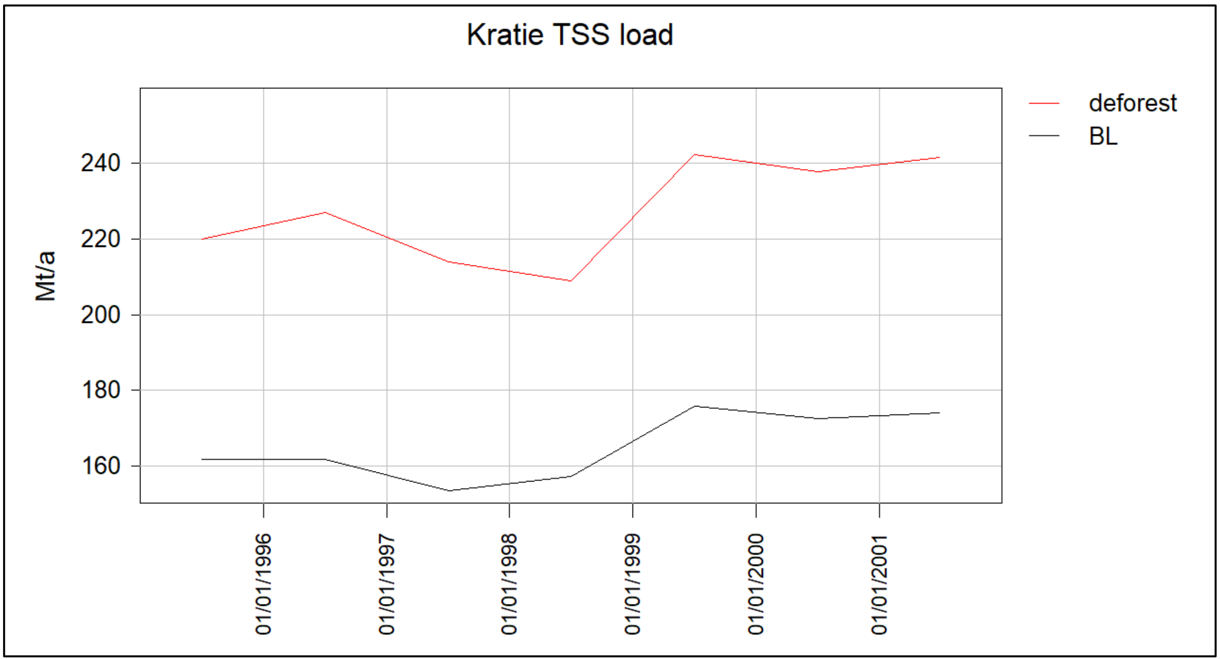


Figure 42 Kratie annual sediment load in baseline (BL) and deforestation scenarios.

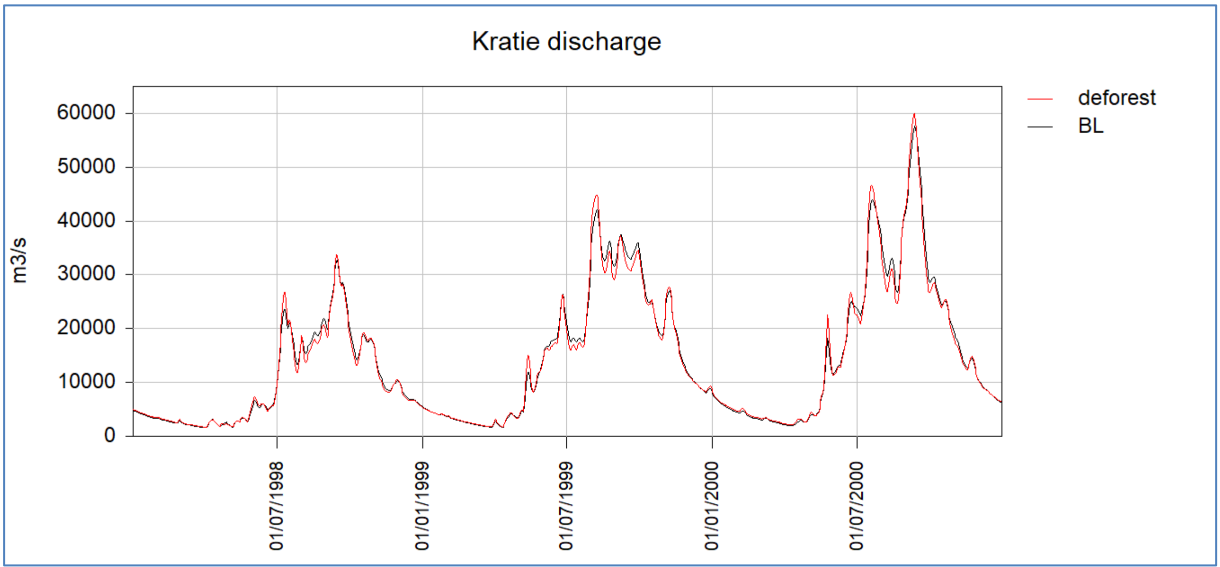


Figure 43 Kratie discharge in baseline (BL) and deforestation scenarios.

13 Scenario impacts on flooding

13.1 Hydropower development

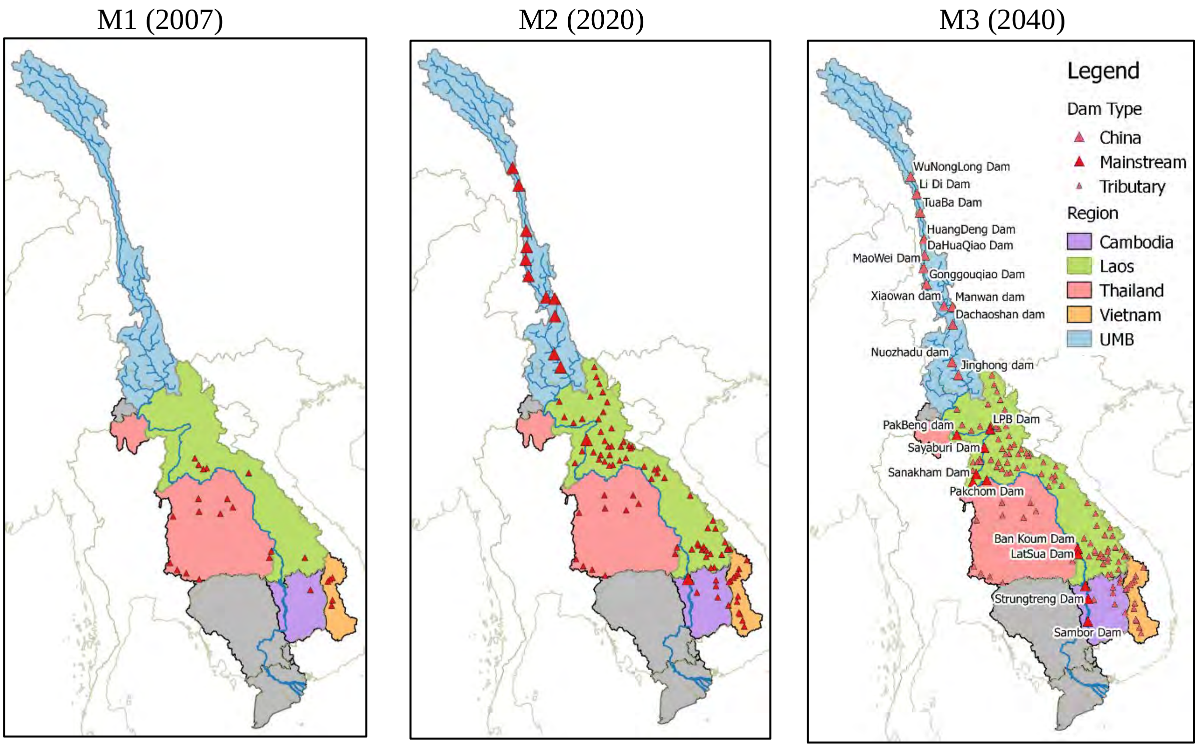


Figure 44. Hydropower reservoir locations in the Mekong Basin for the 2007, 2020 and 2040 scenarios. (ref. Hydropower Thematic Report)

Figure 44 shows hydropower reservoirs in the Mekong Basin for the M1, M2 and M3 scenarios. This can be compared to the hydropower generation capacity development in the five Mekong countries in Figure 45. The China dams have large impact on sediments as most of the sediments (50% – 60%) originate in natural conditions from China and China dams are deep and able trap practically all of the China sediments.

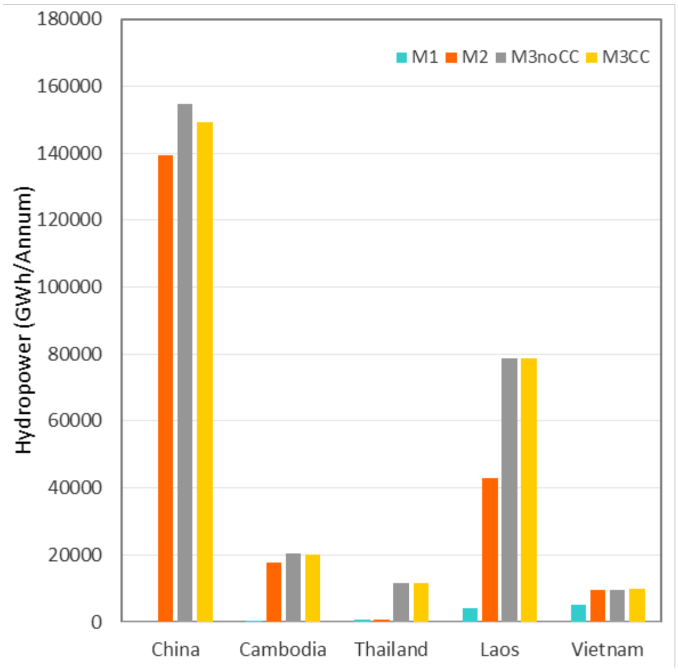


Figure 45. Hydropower generation development in the Mekong Basin for the 2007, 2020 and 2040 scenarios. (ref. Hydropower Thematic Report)

13.2 Scenario flooding changes

Figure 46 shows baseline flood duration and change in 2040 and 2040CC scenarios. For the most part flood duration decreases in the future development scenarios except for some areas in the flood periphery. Also, extreme flood events are reduced as the hydropower reservoirs store peak flood water (Figure 47, 2040 scenario). Climate change can on the other hand increase peak flooding even with the extensive hydropower development ((Figure 47, 2040CC scenario).

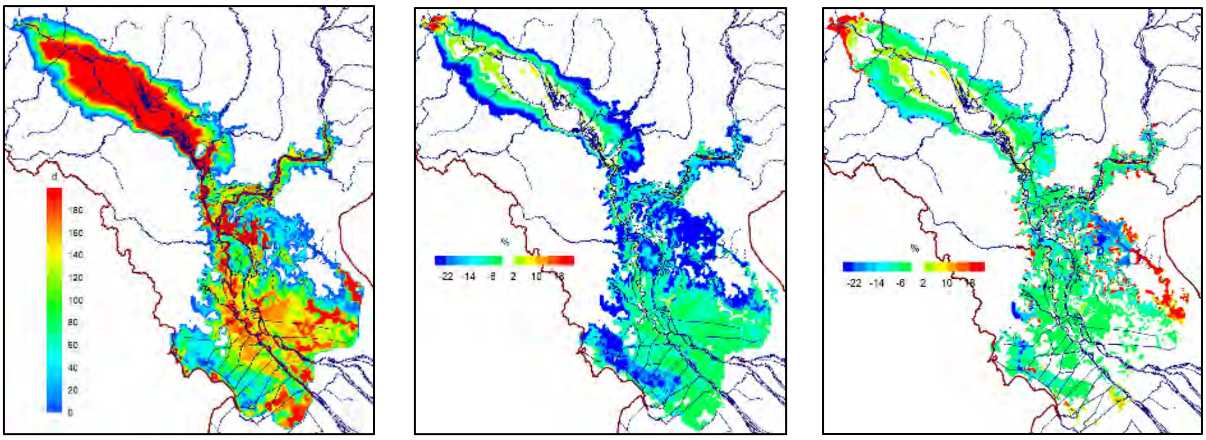


Figure 46. Average flood duration in the baseline (left), 2040 change (middle) and 2040CC change (right).

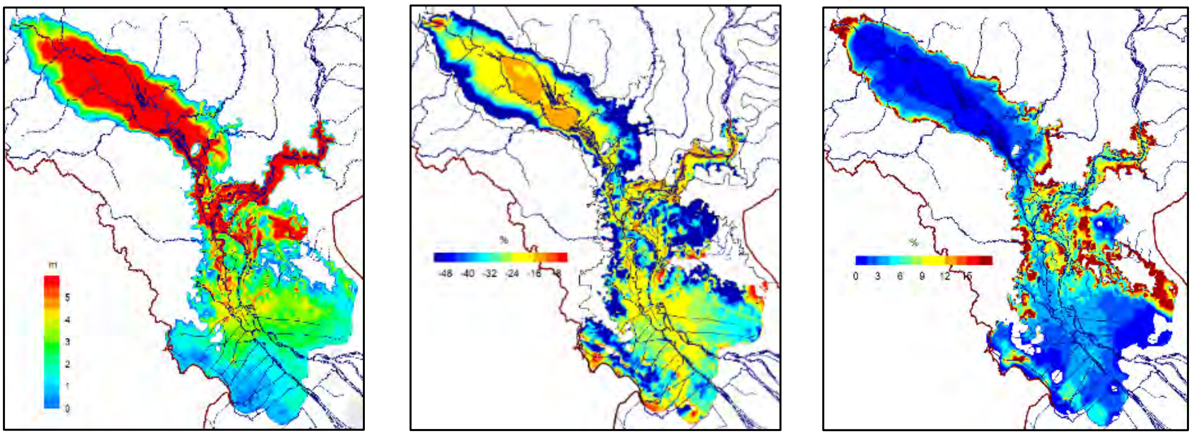


Figure 47. 100 year flood depths in the baseline (left), 2040 change (middle) and 2040CC change (right).

14 Sedimentation scenario changes

Sedimentation changes affect agricultural production and primary production in general. In ecosystems they impact vegetation and can change land use.

14.1 Sediment trapping

Figure 48 shows Mekong sediment loads from China to Kratie in the M1, M2 and M3 scenarios. M3 scenario removes most of the sediments. In this scenario nearly all sediments are trapped before Kratie. M2 scenario maintains 30% of the natural sediment flux in Kratie.

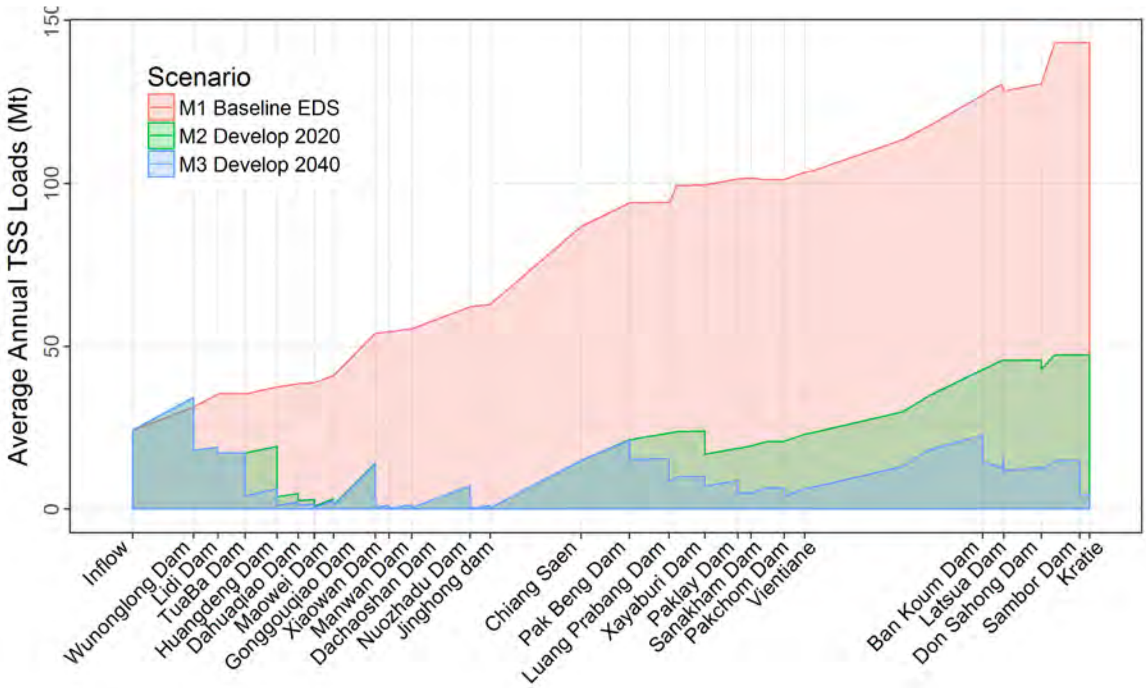


Figure 48. Comparison of average annual TSS loads on the Mekong (and Lancang) River under the three main scenarios without climate change (ref. Modelling Summary Report).

Figure 49 shows impact of climate change on sediment fluxes. Due to more intense wet season rainfall and increased watershed erosion the sediment flux is slightly increased in most of the LMB stations except in Kratie.

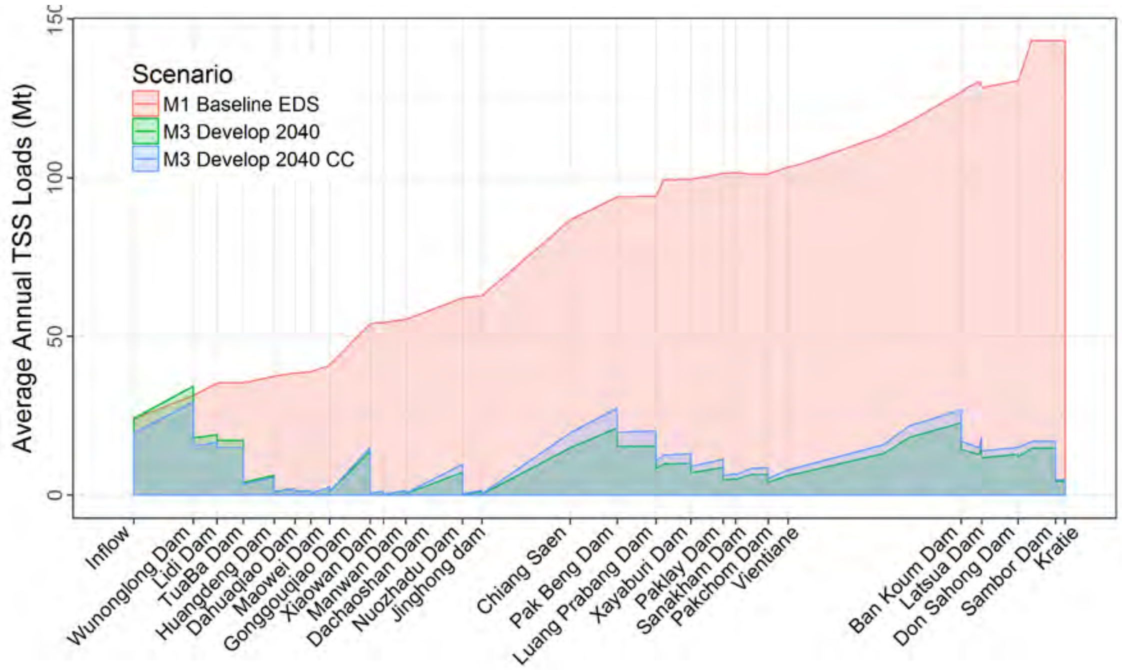


Figure 49. Comparison of average annual TSS loads on the Mekong (and Lancang) River for the Development 2040 scenario with and without climate change. The Baseline scenario results are included for reference (ref. Modelling Summary Report).

Sediment trapping in the tributaries and mainstream as well as sediment entering to Delta is shown in Figure 50. The largest impact between 2007 and 2020 is caused by China dam construction and the largest impact between 2020 and 2040 by Lao hydropower development.

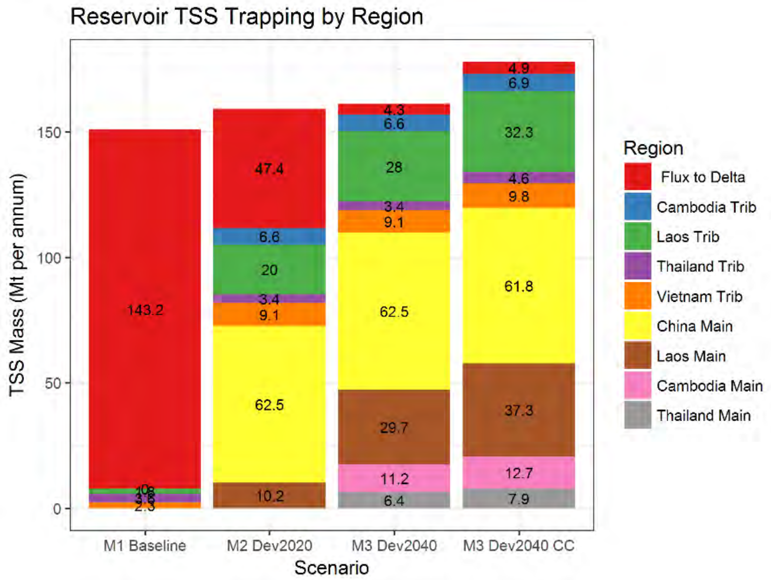


Figure 50. Comparison of the mass of sediment reduced (e.g. reforestation) and trapped by reservoirs within each region and the load entering the delta (red bars) for each of the main scenarios. (ref. Modelling Summary Report)

14.2 Main scenario floodplain and paddy sedimentation in the upstream Kratie SIMA corridor

Annual floodplain and paddy sedimentation per unit area for the upstream Kratie SIMVA zones is shown in the Figure 51 - Figure 54 for the scenarios M1 – M3CC. The sedimentation doesn't correspond directly to any sediment fraction but indicates sedimentation of alluvium, that is fine sediment particles, nutrients and organic material. The sedimentation value in relation to TSS (total suspended sediments) is derived from IWRM Tonle Sap WUP-FIN monitoring and modelling results. It can be seen from the figure that there is very significant variation in between the years depending on the flooding conditions and sediment loads. Differences between the zones derives from their exposure for flooding.

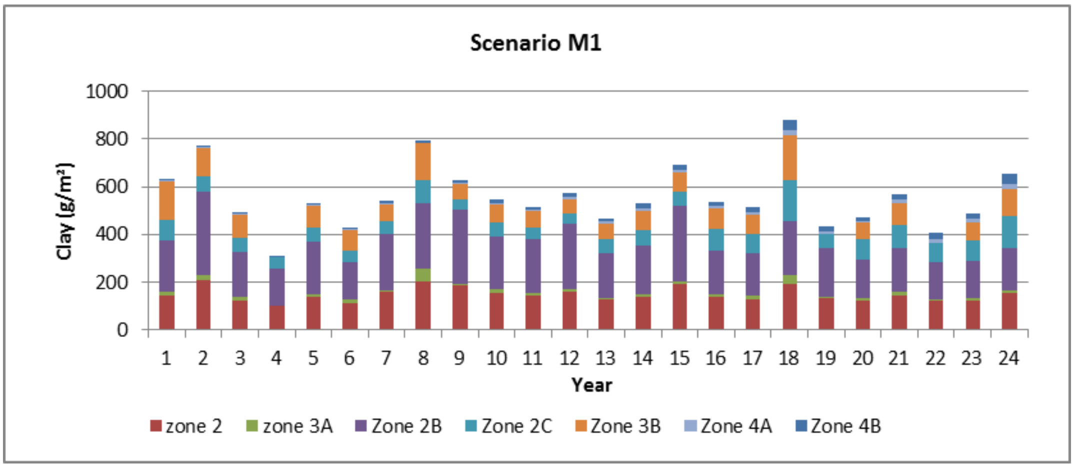


Figure 51. Annual sedimentation for the scenario M1

Figure 52 presents annual sedimentation for the scenario M2. Scenario halves floodplain and paddy sedimentation.

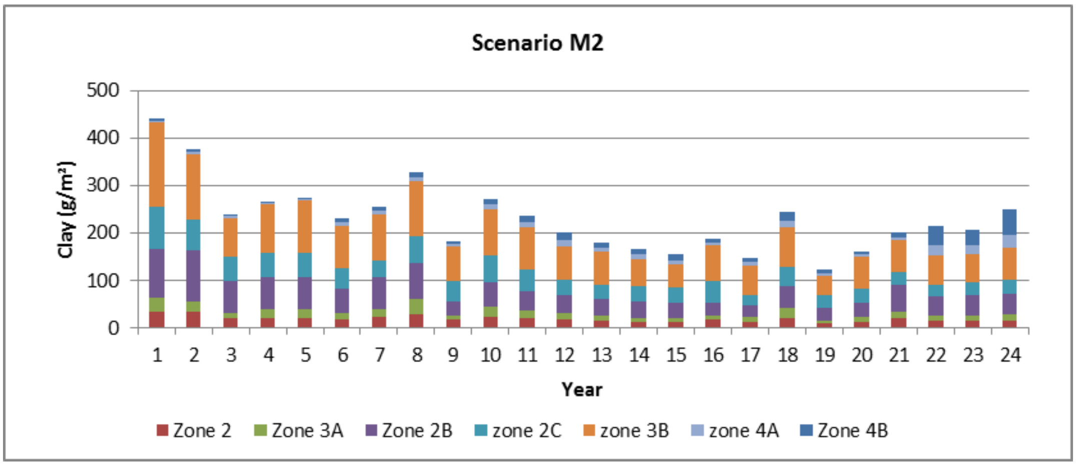


Figure 52. Annual sedimentation for the scenario M2

Figure 53 presents annual sedimentation for the scenario M3. Sedimentation is about one sixth compared to the baseline.

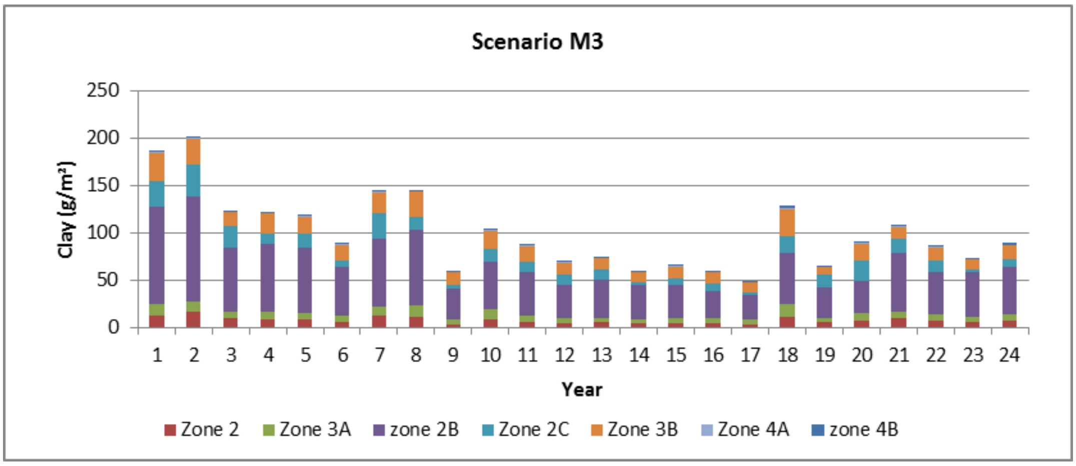


Figure 53. Annual sedimentation for the scenario M3

Figure 54 presents annual sedimentation for the scenario M3CC. In general sedimentation is slightly increased compared to the M3 but it depends on any specific year and its rainfall causing watershed erosion and sediment load transport.

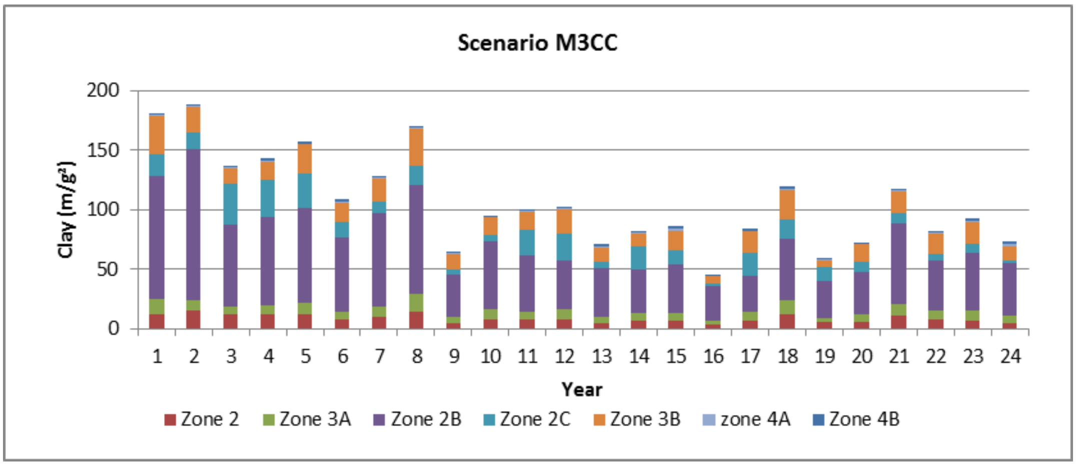
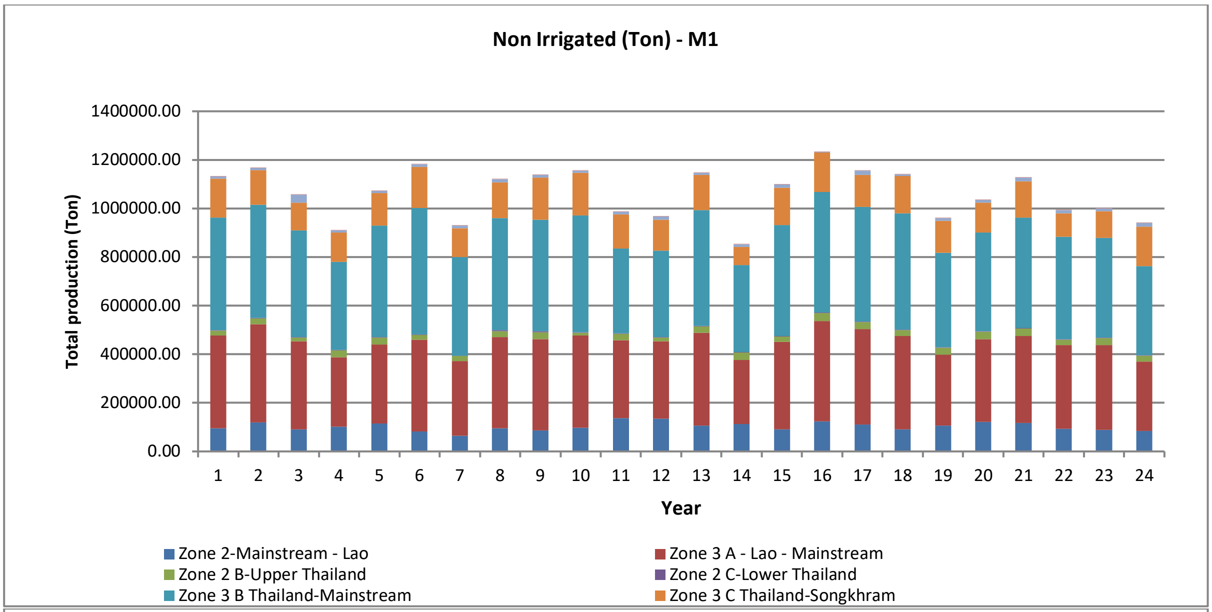


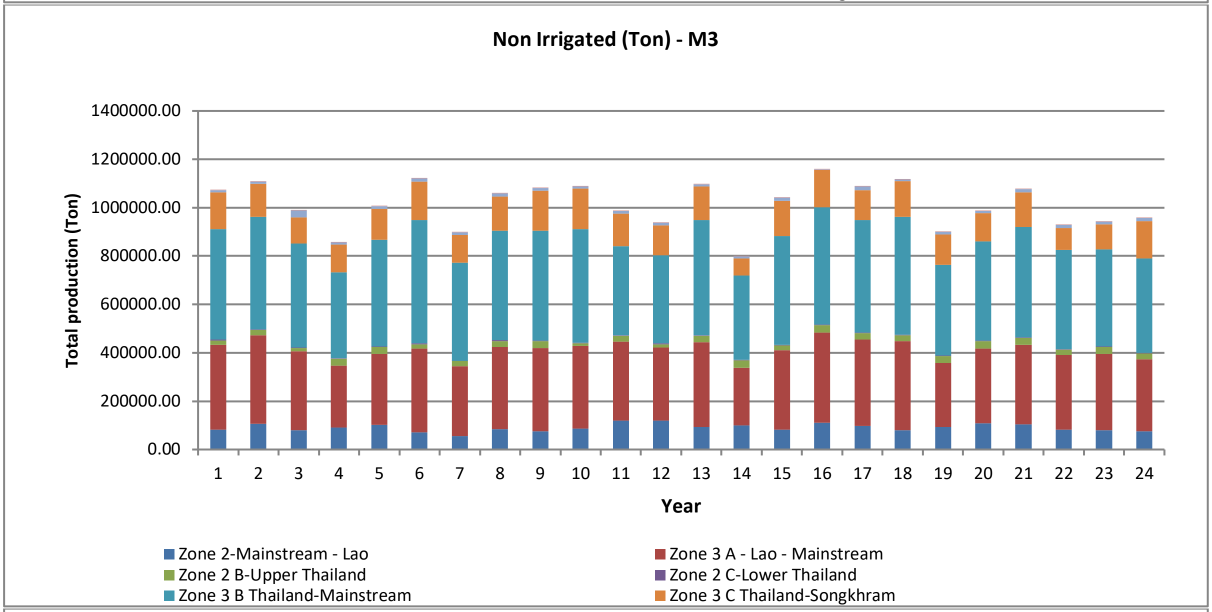
Figure 54. Annual sedimentation for the scenario M3CC

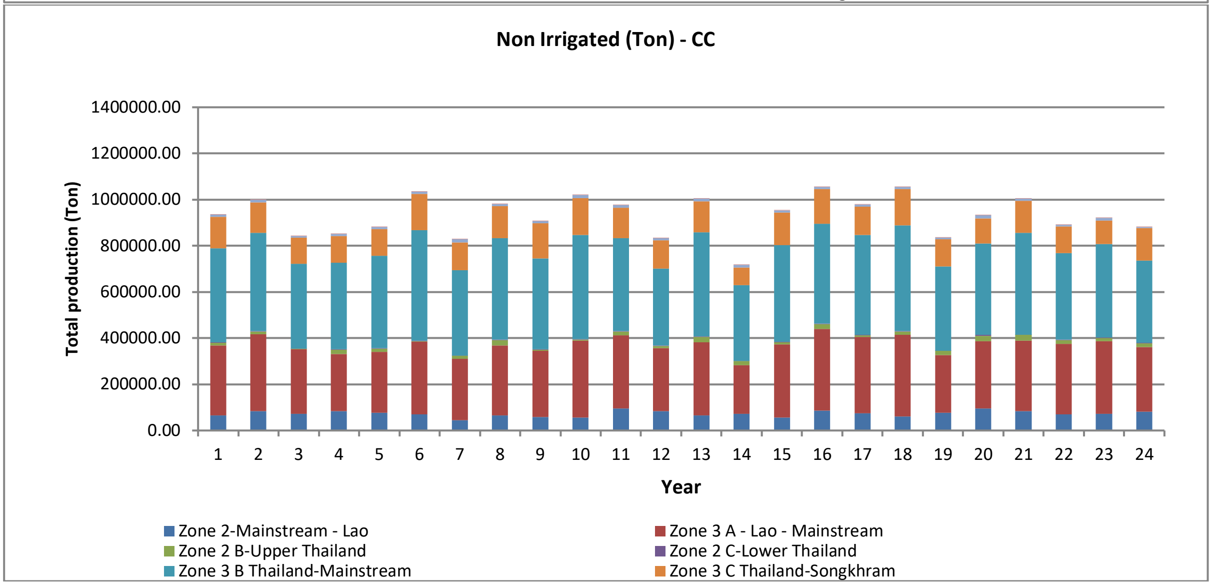
15 Upstream non-irrigated rice production

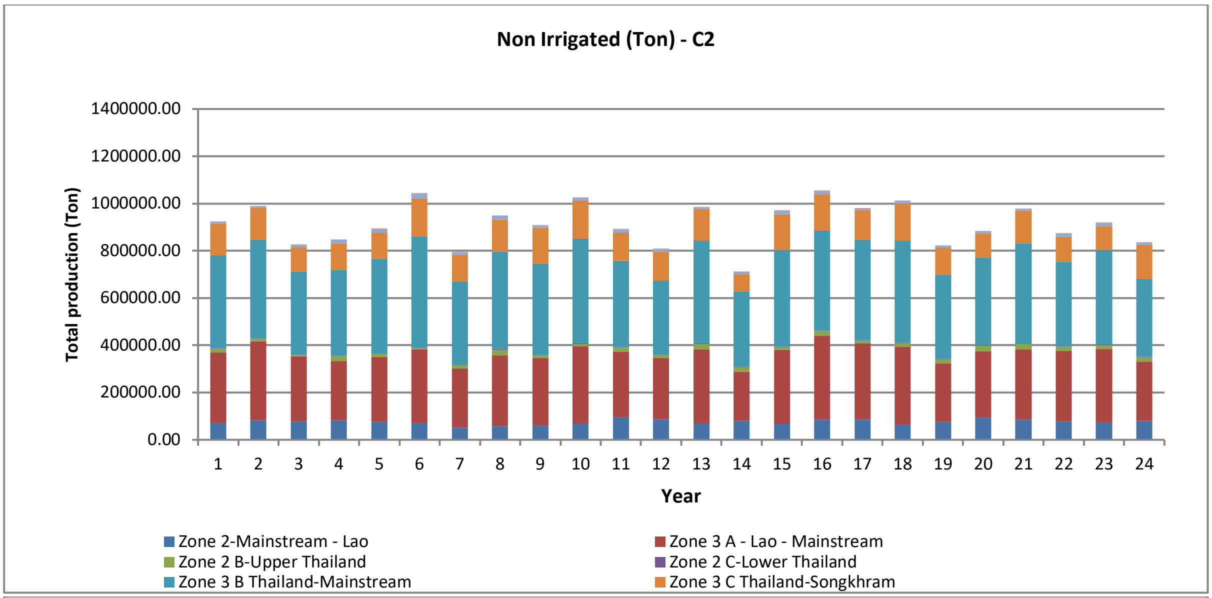
In the model rice is impacted by climatic conditions (precipitation and temperature), sediment input to the paddies (soil fertility), flooding (soil water and flood damage), salinity, CO_2 concentration as well as hydrological characteristics of each paddy area such as water drainage dependent on slope and soil properties.

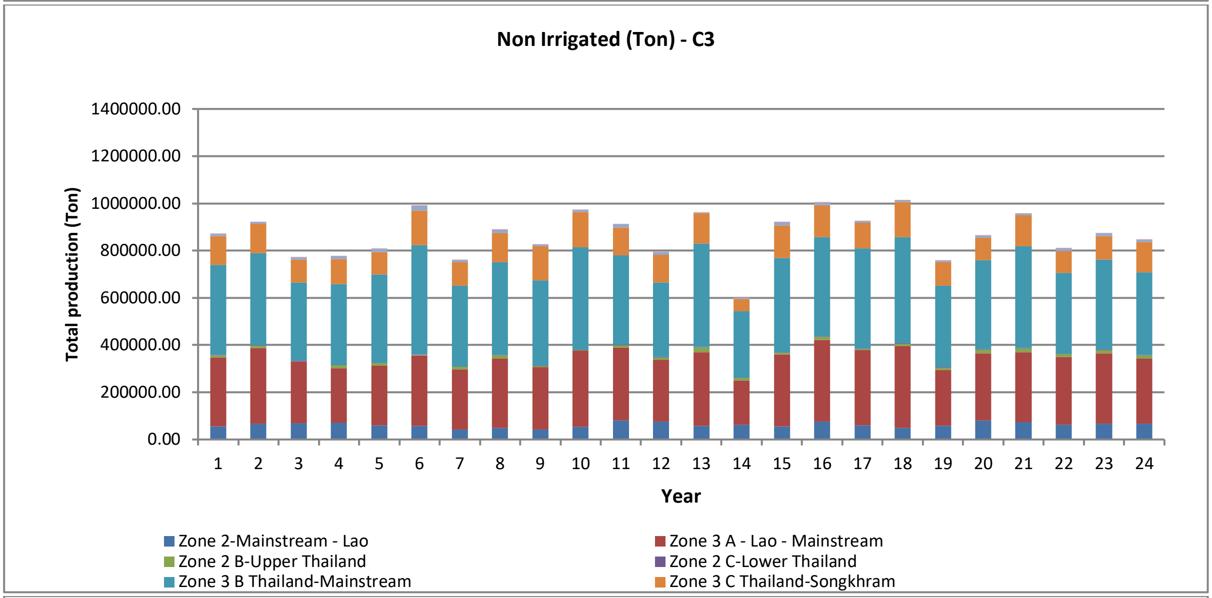
In the Figure 55 shows total non-irrigated rice production in the upper Kratie divided into the zones for the scenarios M1, M3, M3CC, C2, C3, and A2. The other scenarios differ only slightly from these and are not shown. All the climate scenarios decrease production compare to the M3 due to more unfavorable conditions such as non-optimal temperatures, higher soil evaporation and decreased precipitation. The production decrease is most prominent in scenario C3 with consistently drier conditions. A2 has increased rice production compared to the M3 due to increased agricultural area.


Non Irrigated (Ton) - M1
1400000.00
1200000.00
1000000.00
800000.00
600000.00
400000.00
200000.00
0.00
Total production (Ton)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Year
Zone 2-Mainstream - Lao
Zone 3 A - Lao - Mainstream
Zone 2 B-Upper Thailand
Zone 2 C-Lower Thailand
Zone 3 B Thailand-Mainstream
Zone 3 C Thailand-Songkhram


Non Irrigated (Ton) - M3
1400000.00
1200000.00
1000000.00
800000.00
600000.00
400000.00
200000.00
0.00
Total production (Ton)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Year
Zone 2-Mainstream - Lao
Zone 3 A - Lao - Mainstream
Zone 2 B-Upper Thailand
Zone 2 C-Lower Thailand
Zone 3 B Thailand-Mainstream
Zone 3 C Thailand-Songkhram


Non Irrigated (Ton) - CC
1400000.00
1200000.00
1000000.00
800000.00
600000.00
400000.00
200000.00
0.00
Total production (Ton)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Year
Zone 2-Mainstream - Lao
Zone 3 A - Lao - Mainstream
Zone 2 B-Upper Thailand
Zone 2 C-Lower Thailand
Zone 3 B Thailand-Mainstream
Zone 3 C Thailand-Songkhram





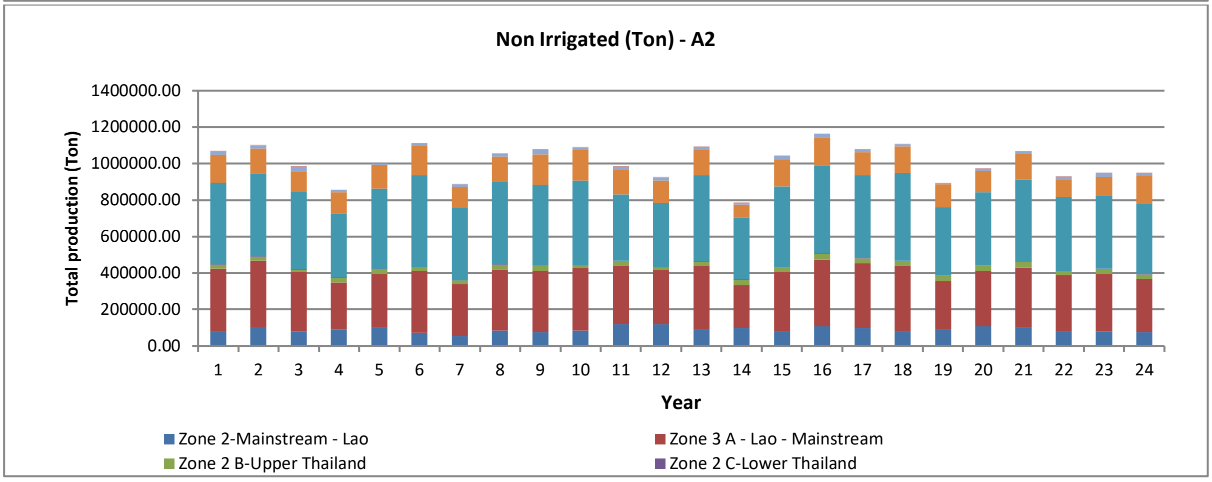


Figure 55. Annual variation of total rice production in the upper Kratie zones for the scenarios M1, M3, M3CC, M2, M3, and A2.

The variation in non-irrigated rice production between the scenarios can be seen in the figures Figure 56-Figure 58. As explained above the largest differences are between the climate and agricultural area scenarios.

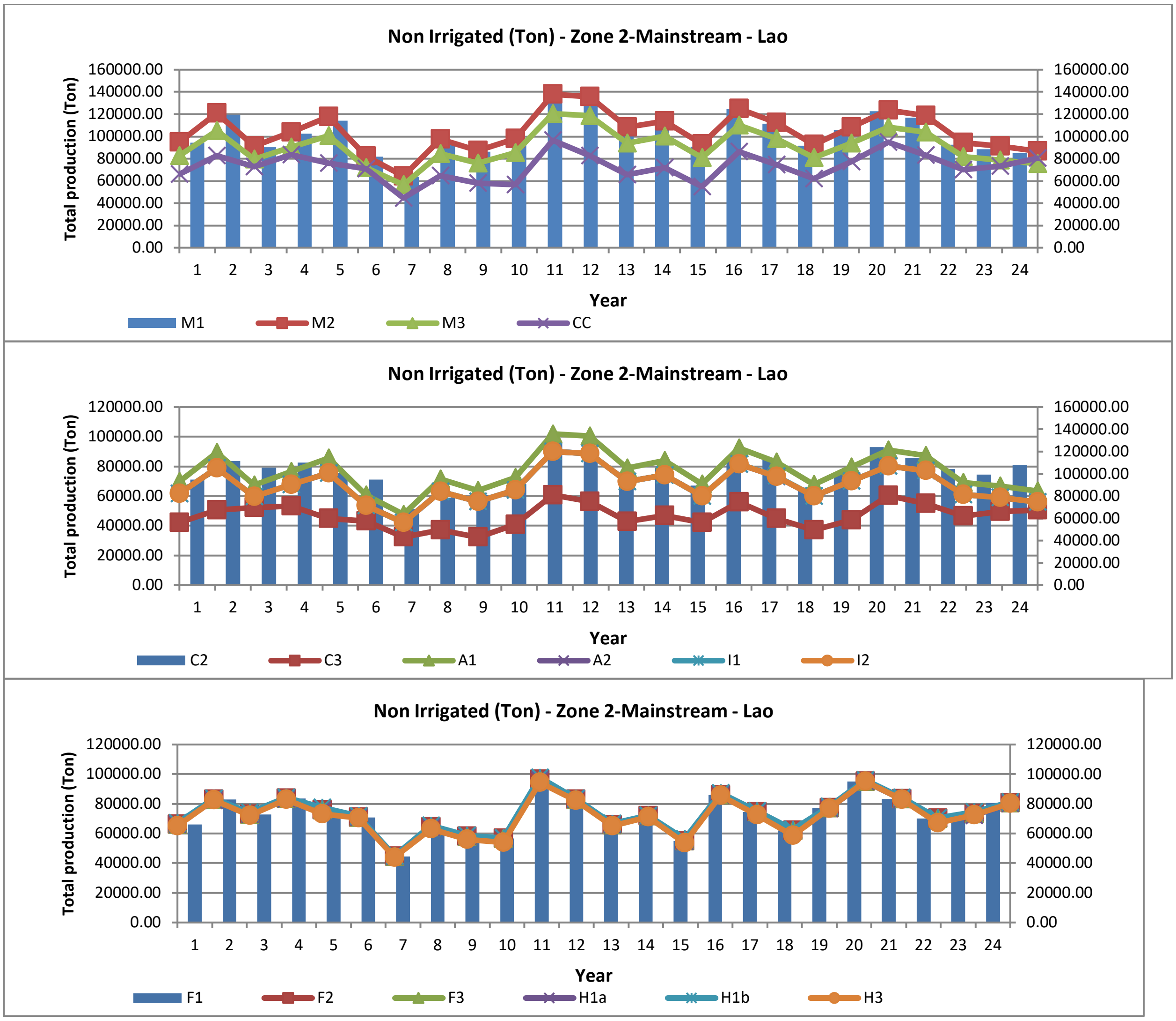
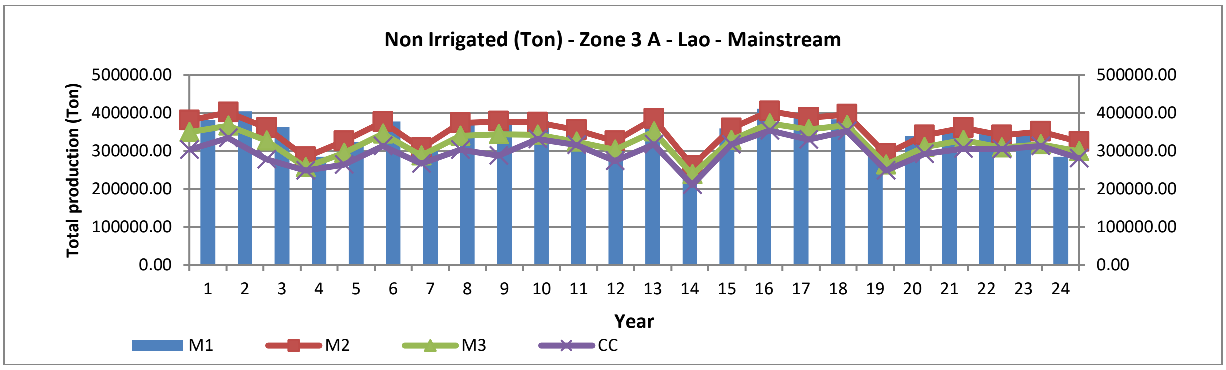


Figure 56. Annual variation of total rice production in the Zone 2 for all scenarios. Observe that scales are different for the bars (left scale) and for the time series (right scale).



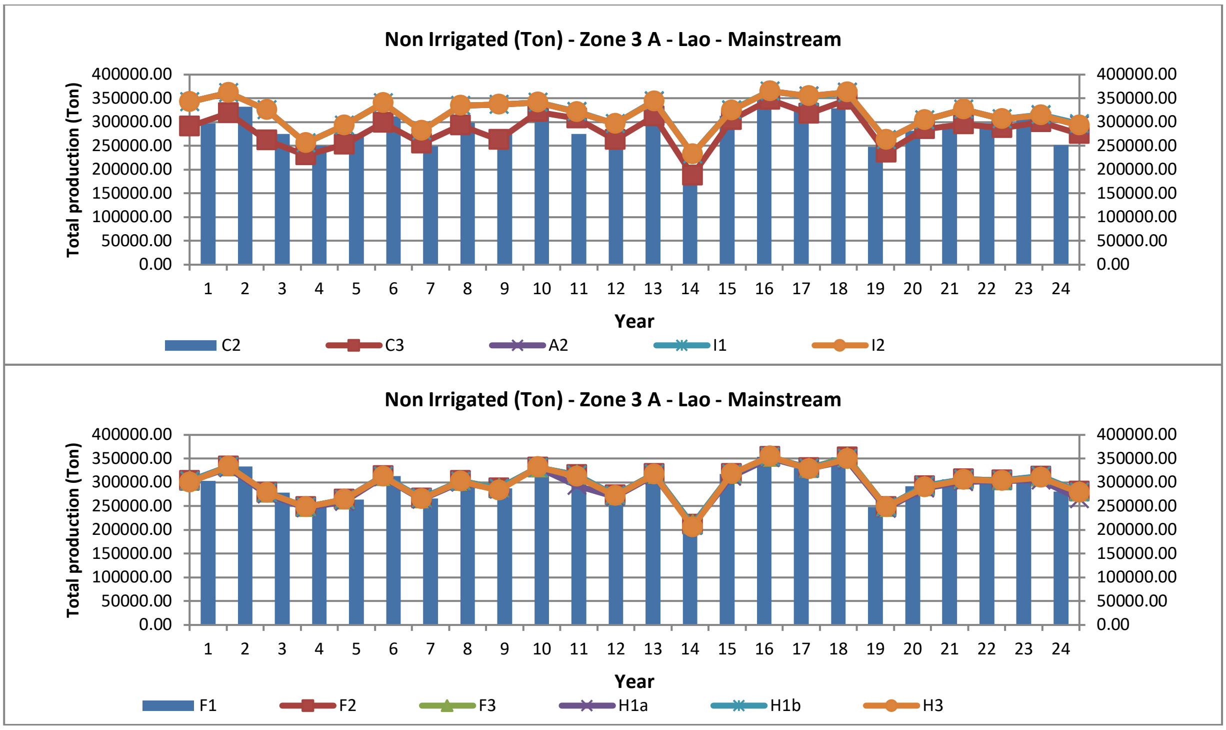


Figure 57. Annual variation of total rice production in the Zone 3A for all scenarios. Observe that scales are different for the bars (left scale) and for the time series (right scale).

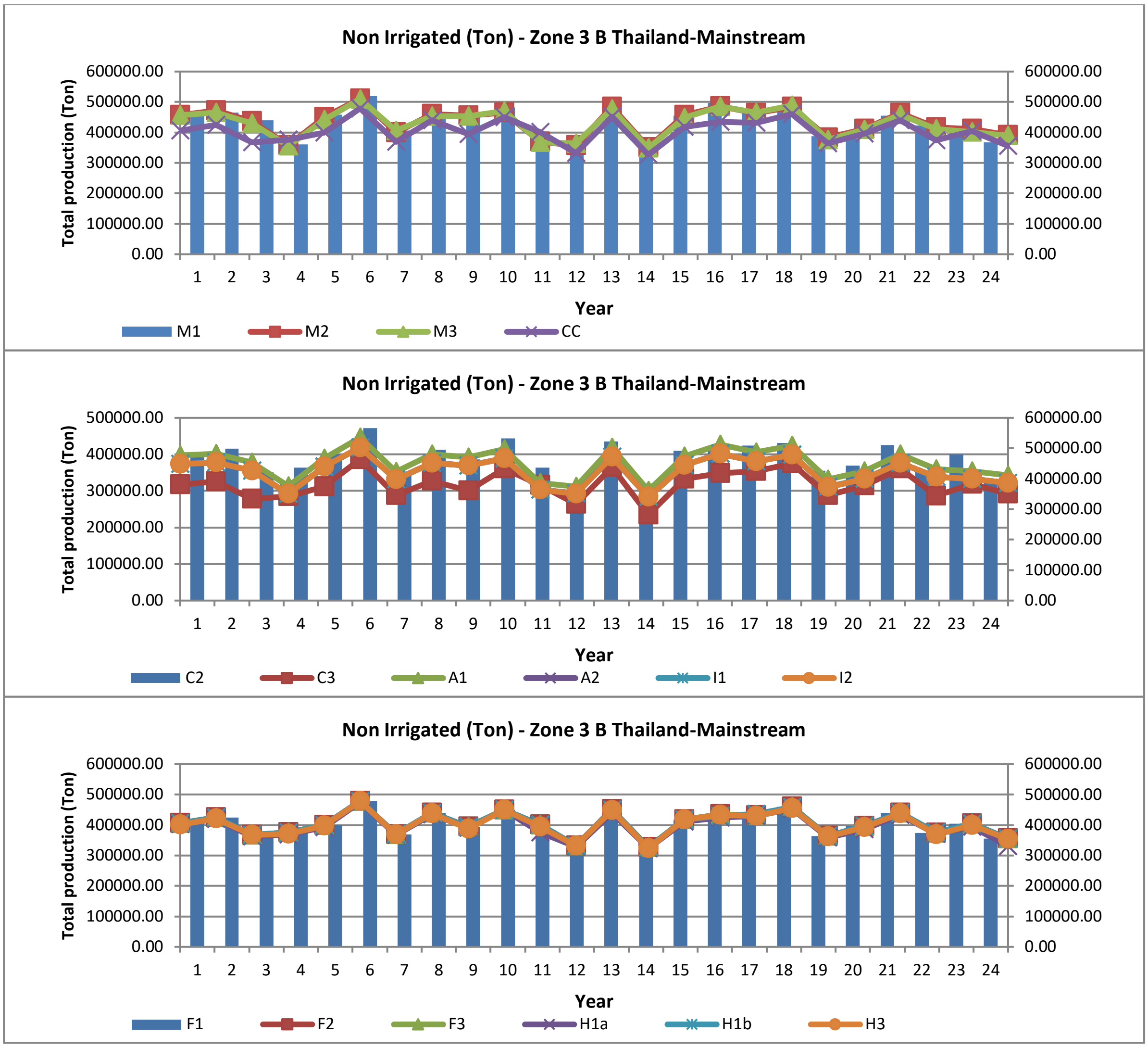


Figure 58. Annual variation of total rice production in the Zone 3B for all scenarios. Observe that scales are different for the bars (left scale) and for the time series (right scale).

16 Downstream Kratie conditions and non-irrigated rice production

16.1 Scenario flooding characteristics

Flooding affects rice production in terms of available growing period and flood damages. The modelling results in this and subsequent chapters are presented for the Zones 4C (Cambodia from Kratie to Vietnam border), 6A (Vietnam Delta freshwater), 6B (central saline Vietnam Delta) and 6C (Cà Mau Peninsula) (see **Figure 15.** Model output areas for the socio-economic analysis).

Flooded areas remain relatively constant for Zone 4C. In the coastal provinces sea level and flood protections affect flooding and flooded areas change more. The flooded areas are divided basically into two groups with and without sea level rise (Figure 59 and Figure 60). The former includes here M1, M2, M3 and M3CC and the latter rest. The exception for the rule is flood protection scenario F1 which decreases flooding to the baseline level. It should be noted that in the model flooding areas depend on

ISIS water levels in the river channels and are not affected directly by flood protections. This exaggerates flooding areas. In the future, when maps of flood protections become available, dykes can be implemented in the model.

Figure 59. Zone 6A annual flooded area

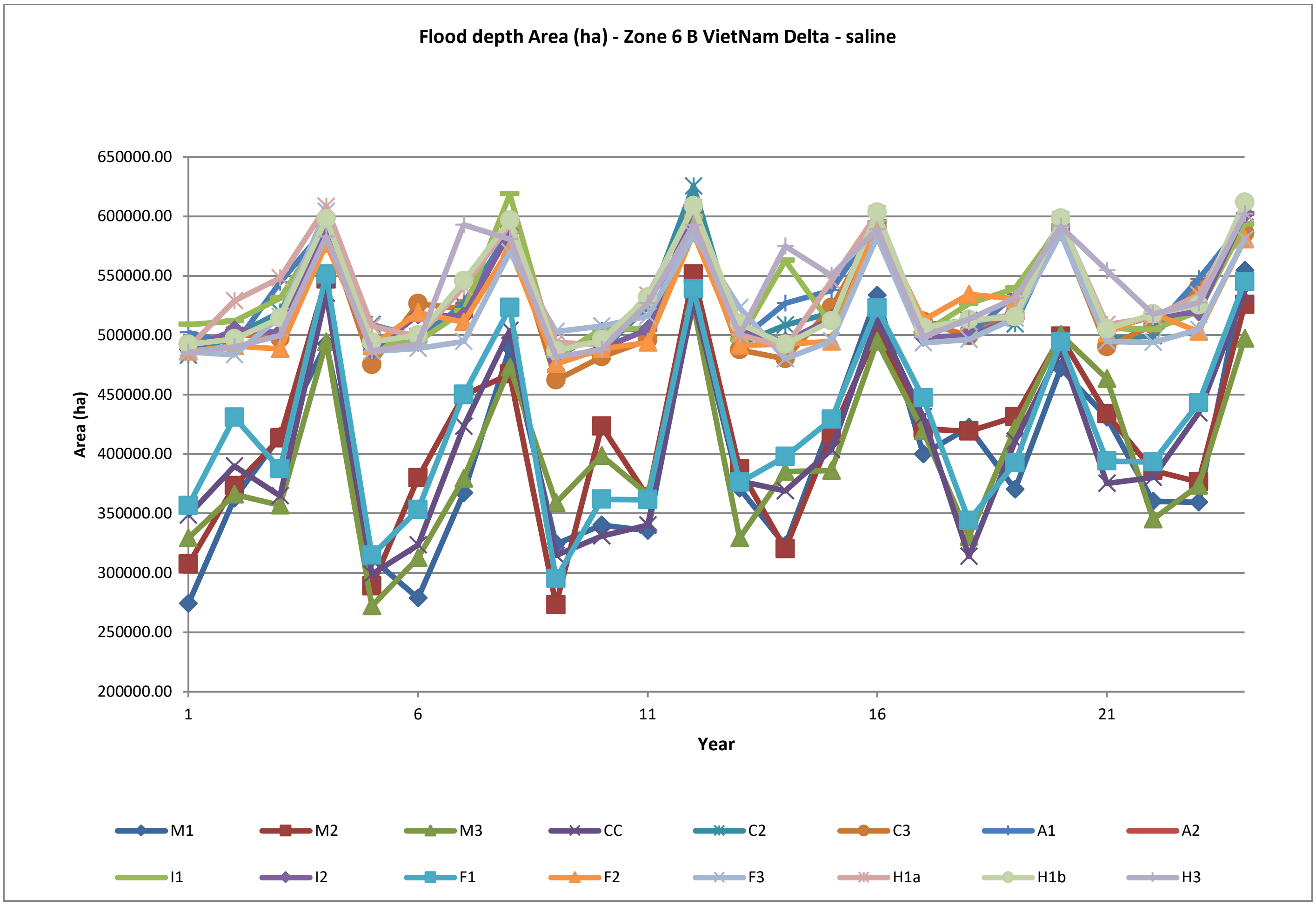


Figure 60. Zone 6B annual flooded area

Average annual flood depth for all scenarios is shown in Figure 61. Baseline has the highest average flood depth values whereas the dry C3 scenarios has lowest. Hydropower construction lowers the flooding depths.

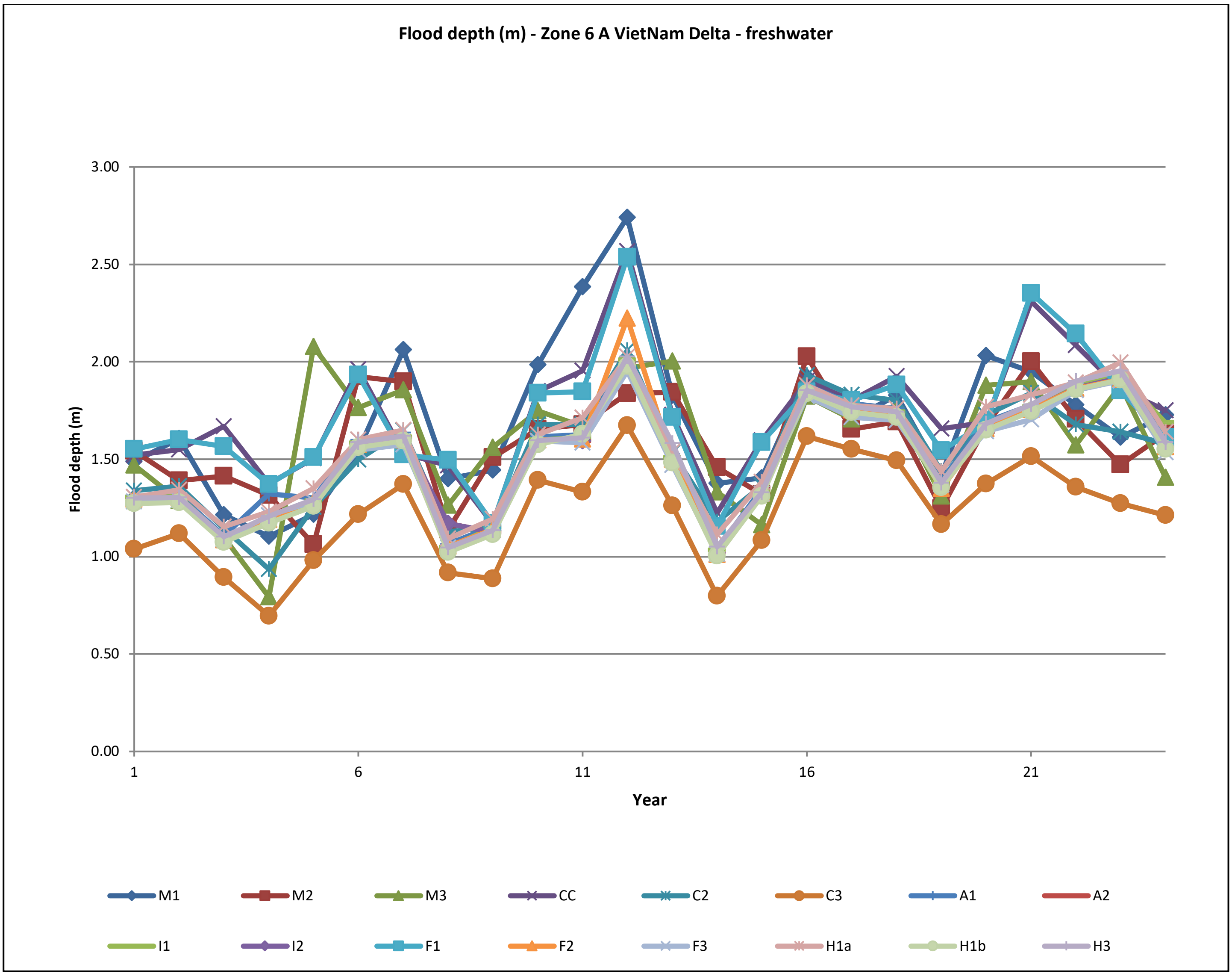


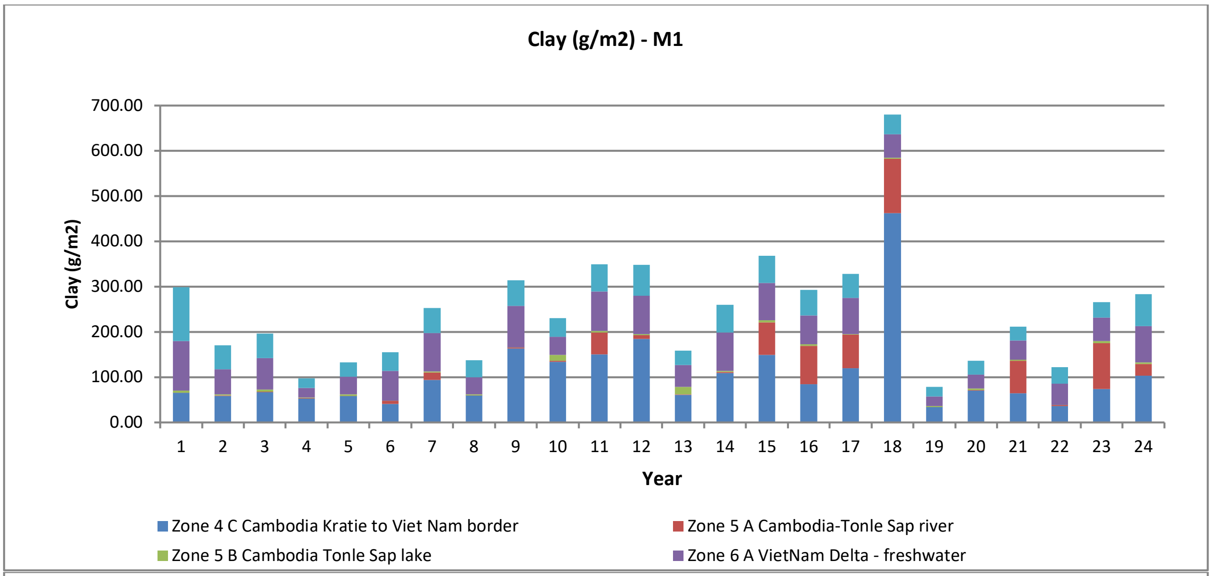
Figure 61. Average annual flood depth for Zone 6A.

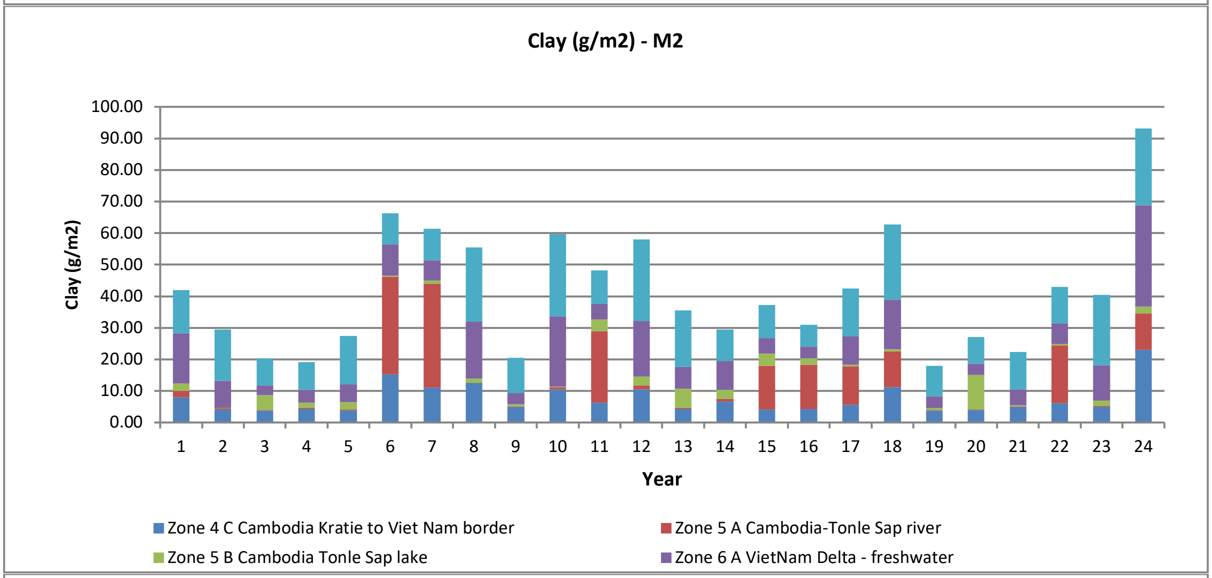
The flood graphs show that scenarios A1 and A2 have practically no impact on flooding. They show also that flooding decreases by the hydropower development.

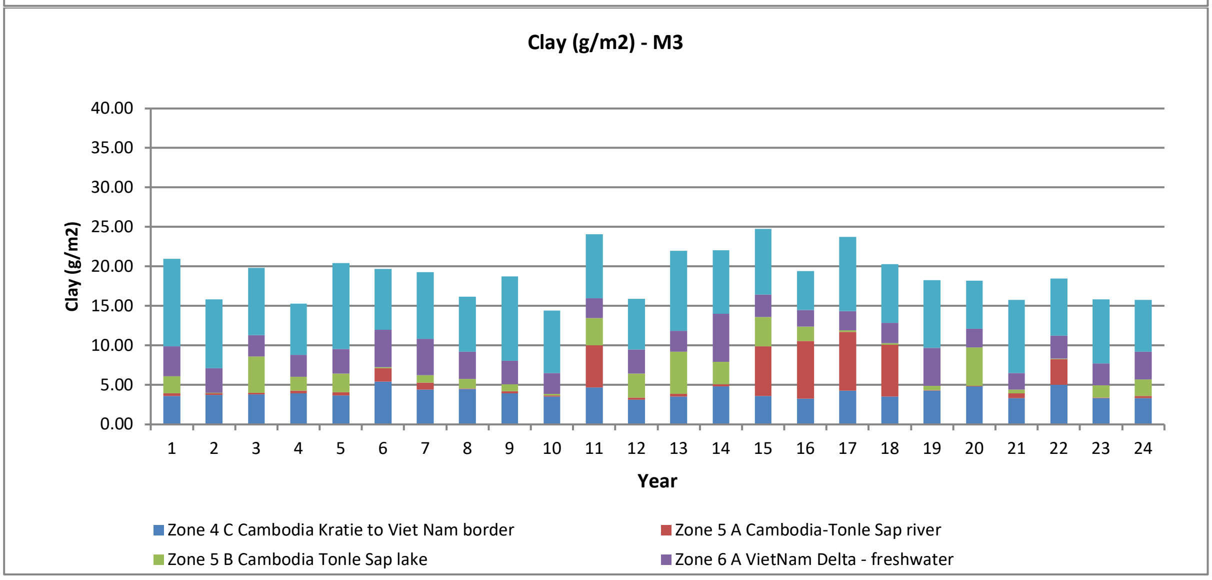
16.2 Scenario results for sedimentation

Clay has been taken here as an indicator for overall sedimentation. It indicates soil fertility and Delta system productivity. Also silt and sand have been also computed with the model but as the productivity model has been calibrated for the clay only the other results are not presented.

Based on the Figure 62 the highest sedimentation rates in the Delta are in Zones 4C and 6A. This is logical as these are central areas having strongest impact from the Mekong. Scenario M2 collapses sedimentation rates about 70% and M3 further halves them. The M3CC climate change scenario slightly increases the rates compared to the M3 due to more intense rainfall and watershed erosion increasing downstream sediment loads. These very large changes in sediment input to the floodplains have major impact to the productivity of the Delta system as can be seen from the subsequent chapters for rice and fish production.


Clay (g/m2) - M1
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
Clay (g/m2)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Year
Zone 4 C Cambodia Kratie to Viet Nam border
Zone 5 A Cambodia-Tonle Sap river
Zone 5 B Cambodia Tonle Sap lake
Zone 6 A VietNam Delta - freshwater


Clay (g/m2) - M2
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Clay (g/m2)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Year
Zone 4 C Cambodia Kratie to Viet Nam border
Zone 5 A Cambodia-Tonle Sap river
Zone 5 B Cambodia Tonle Sap lake
Zone 6 A VietNam Delta - freshwater


Clay (g/m2) - M3
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Clay (g/m2)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Year
Zone 4 C Cambodia Kratie to Viet Nam border
Zone 5 A Cambodia-Tonle Sap river
Zone 5 B Cambodia Tonle Sap lake
Zone 6 A VietNam Delta - freshwater

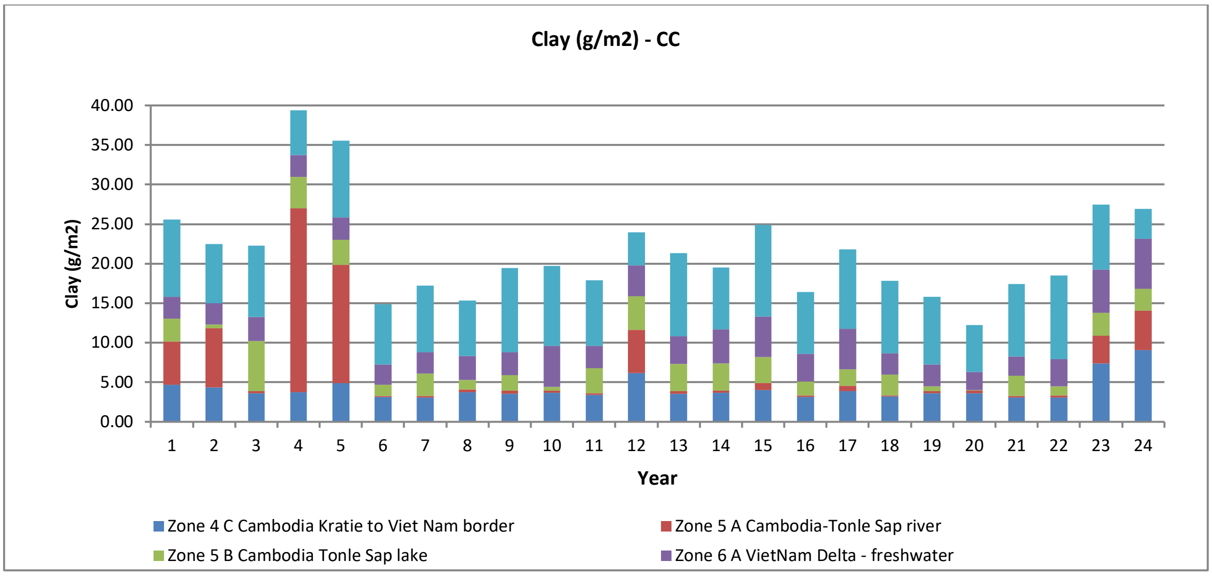
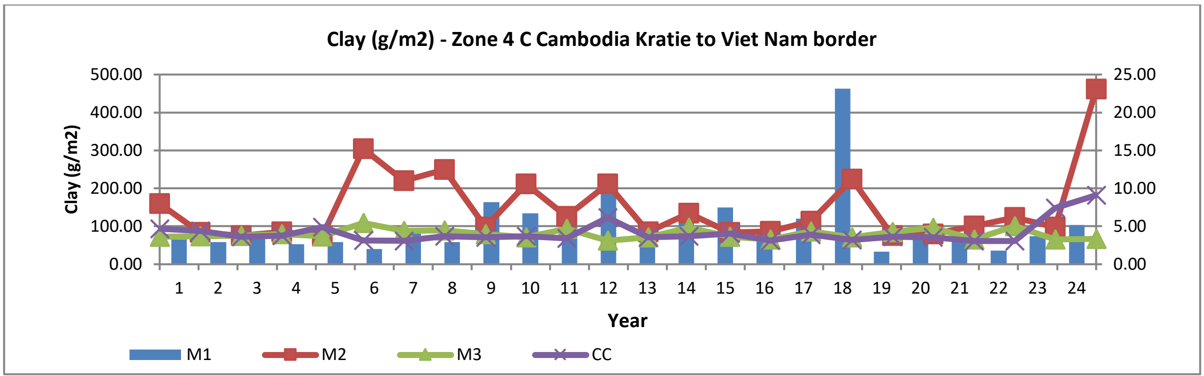
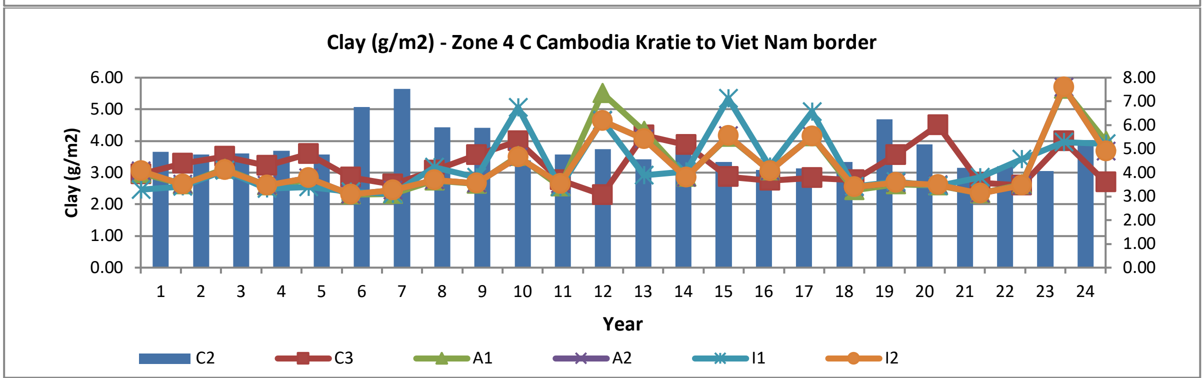


Figure 62. Annual variation of sedimentation rates for the main scenarios.

Clay annual sedimentation rates for the Zone 6A are shown in the Figure 63. Similar to the upstream results also downstream sediment inputs to the floodplains are maintained well with the H1a and H1b hydropower scenarios.





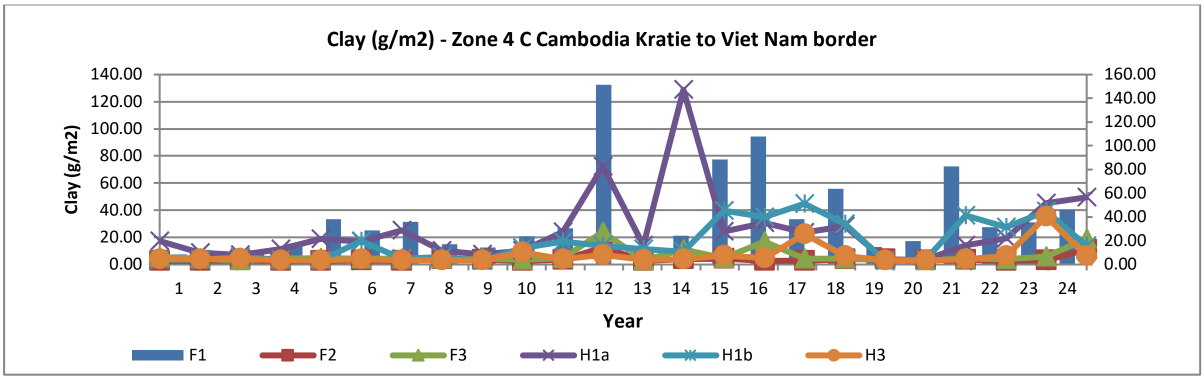
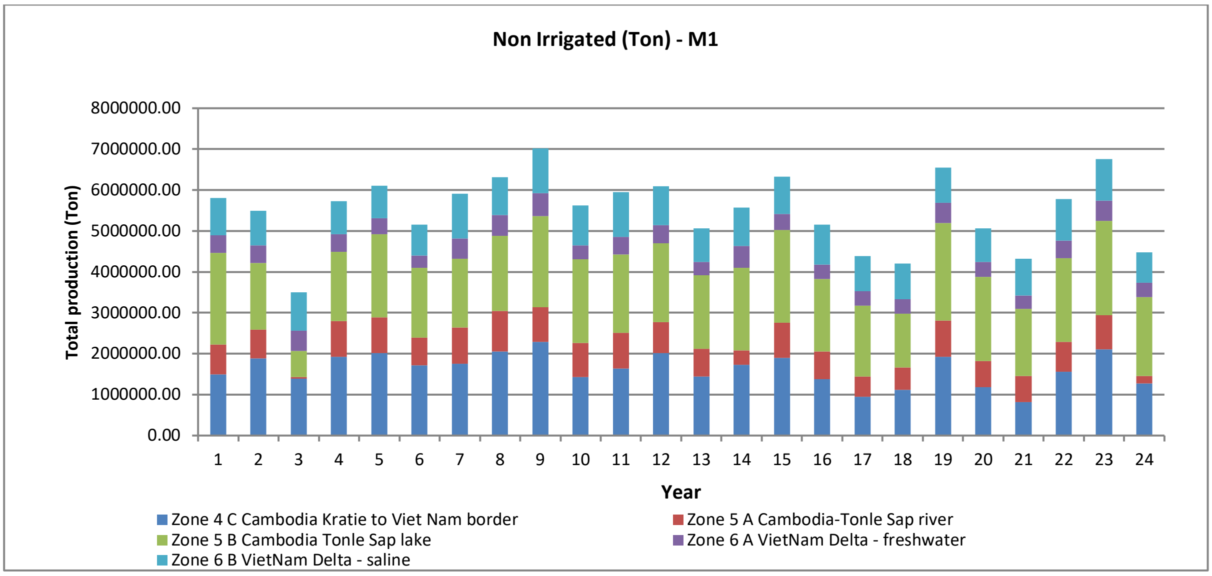
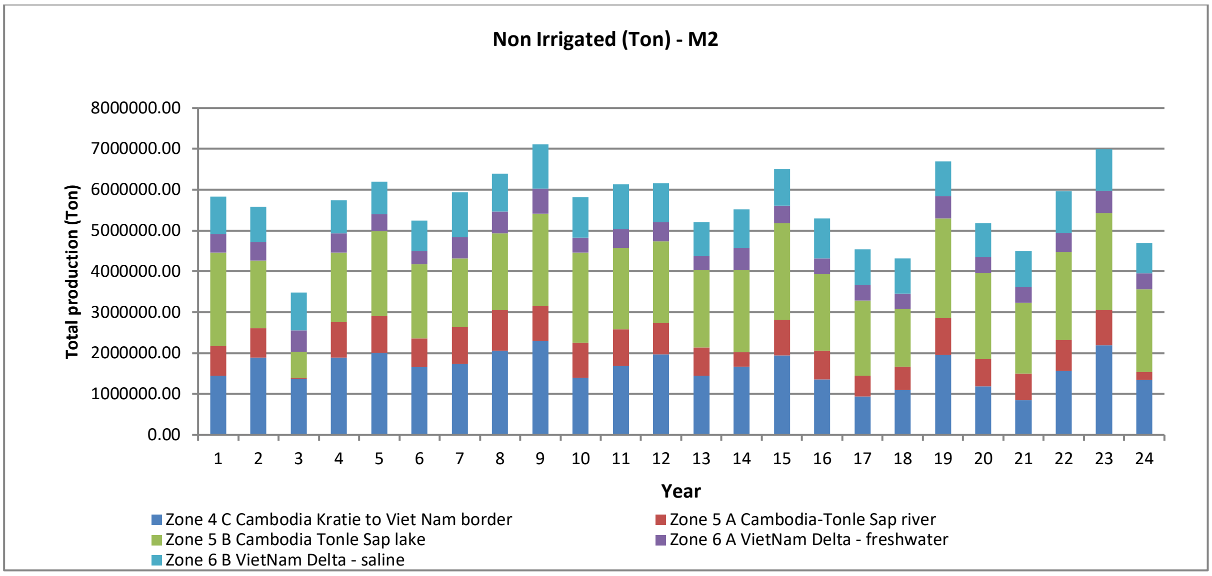


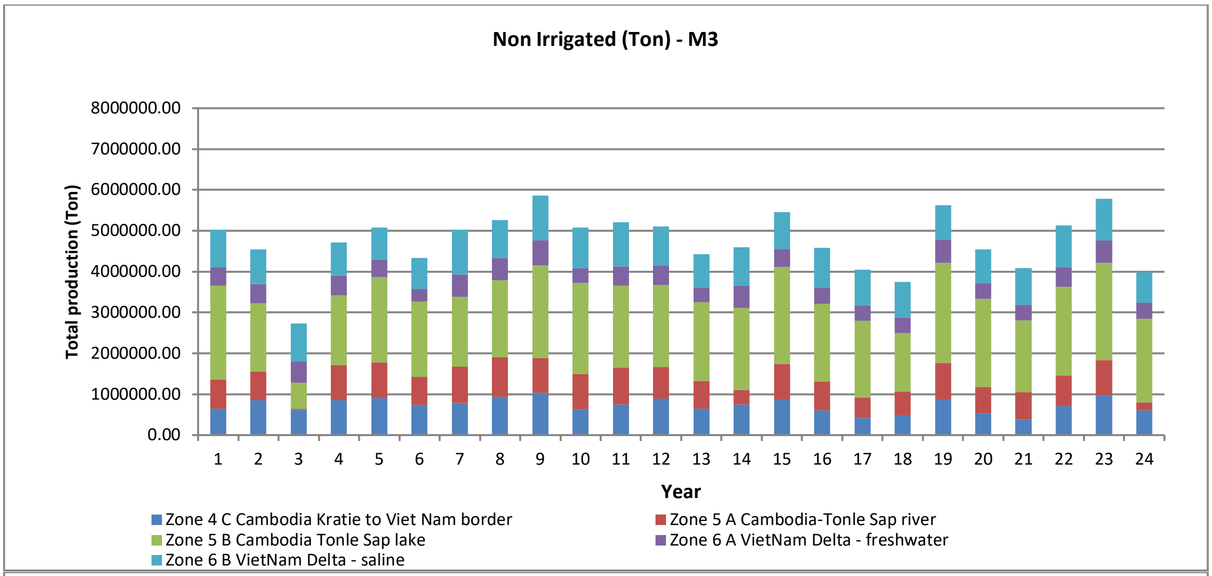
Figure 63. Annual variation of clay floodplain sedimentation for the all scenarios for Zone 4C. Observe that scales are different for the bars (left scale) and for the time series (right scale).

16.3 Scenario results for rice production

Combined Cambodia and Vietnam Delta annual non-irrigated rice production for the main scenarios is presented in Figure 64. Although flooding, sediment input and climate change have impact have impact on production, the change in agricultural area in Cambodia has by far largest impact between M1/M2 and M3/M3CC. In M3 and M3CC non-irrigated agriculture is transformed into irrigated one.







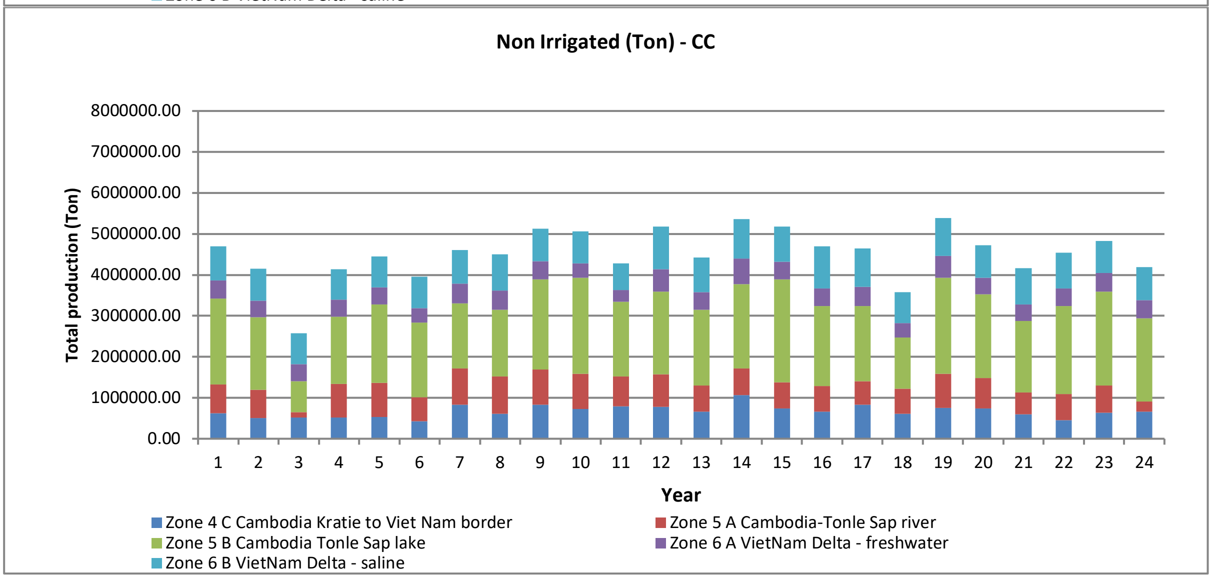


Figure 64. Annual variation of total Cambodia and Vietnam Delta non-irrigated rice production.

In the sub-scenarios scenario A1 stands out with very high rice production (Figure 65) for the Cambodian floodplains (Zone 4C). This is because of substantial increase of non-irrigated agriculture area in Cambodia for the scenario A1.

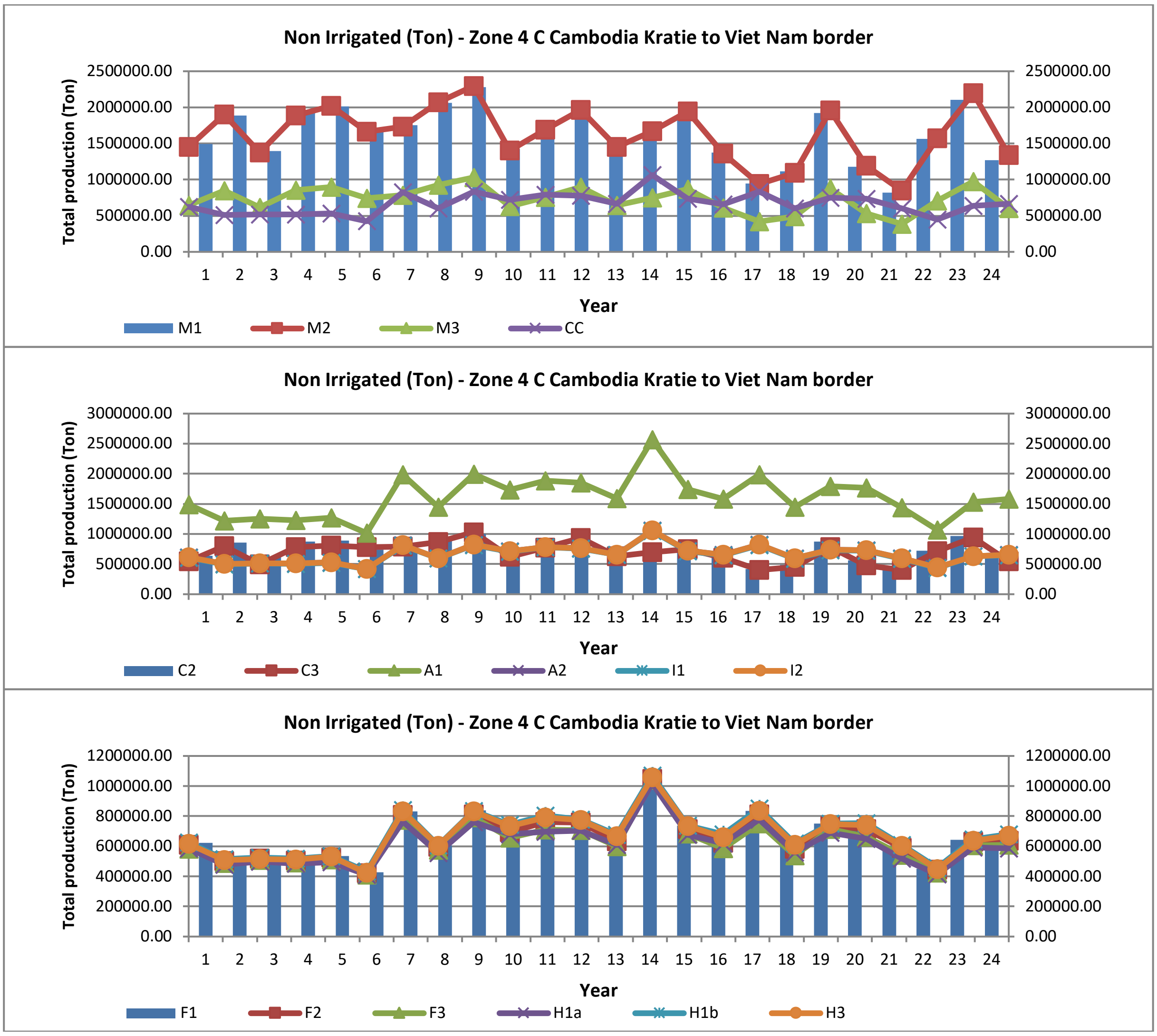


Figure 65. Sub-scenario rice production for non-irrigated rice for the Zone 4C. Observe that scales are different for the bars (left scale) and for the time series (right scale).

17 Tonle Sap impacts on non-irrigated rice production (Supplementary chapter)

DSF modelling covers Tonle Sap watershed. This chapter focuses on complementary information on the climate change scenario impacts on water security, watershed erosion and crop yields. Special focus is on the climate change scenario C3 which is dryer and has larger impact than scenarios C1 and C2.

As no station climate projections for the Tonle Sap were not available precipitation projections have been computed with the IWRM modelling software based on the SIMCLIM projections obtained for Phnom

Penh precipitation. SWAT projections have been available, but they are not for the original observation stations used in the IWRM model. An example of monthly average precipitation for the different climate scenarios is shown in Figure 66 for the Kampong Thom station for the year 1993. C3 is consistently drier than the other scenarios and October and November have increased precipitation for October and November compared to the baseline observed values.

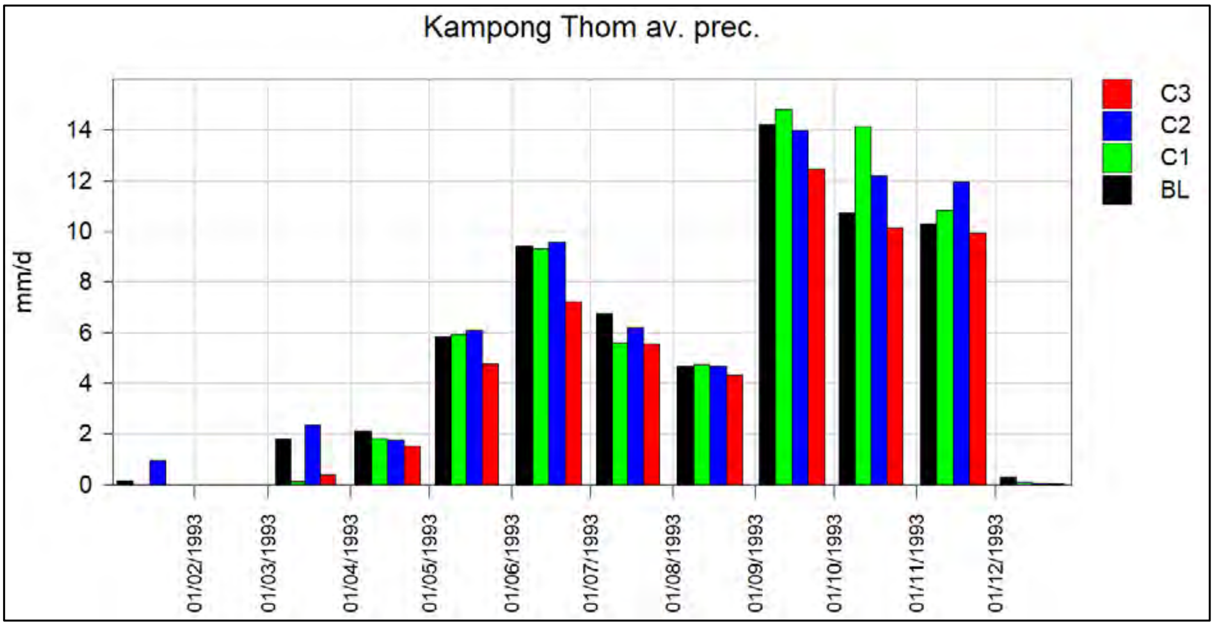


Figure 66. Kampong Thom average monthly rainfall during 1993 for the scenarios baseline (M1), C1 (M3CC), C2 and C3.

Decreased rainfall, hotter temperatures and increased evaporation affect the water security in the Tonle Sap watershed for the scenario C3. In Figure 67 shows dry season model soil layer 2 (0.2 m – 3 m) water content. The soil in scenario C3 is up to 50% drier than in the baseline.

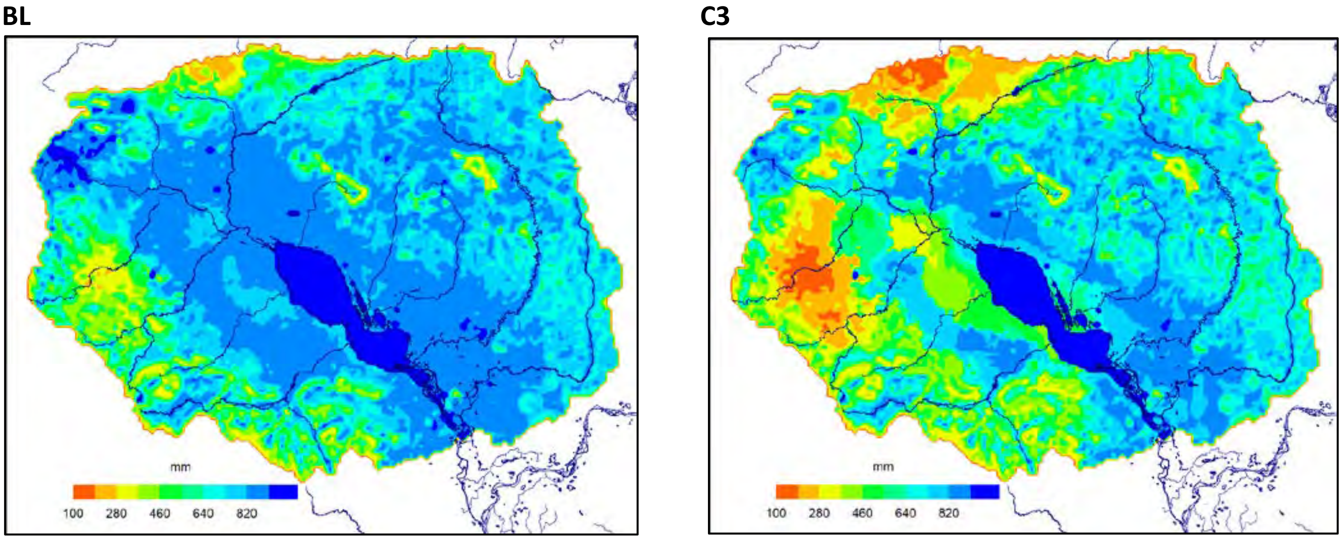


Figure 67. Model soil layer 2 (depth 0.2 m – 3 m) average water content for the dry season.

The drier conditions affect also groundwater as can be seen in the Figure 68: drier conditions drive groundwater deeper into the ground. It should be noted that the groundwater model has not been calibrated nor verified with monitoring data, so the results are illustrative and indicative only.

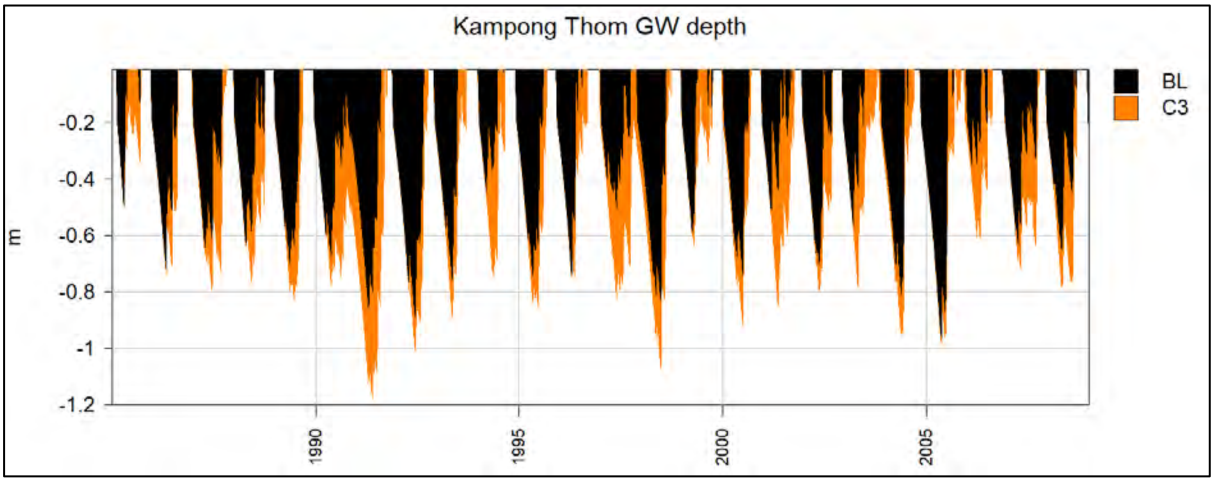


Figure 68. Groundwater depth in Kampong Thom for the baseline (BL) and C3 scenarios.

Rainfall affects soil erosion. Figure 69 shows Kampong Thom annual agricultural area erosion for climate change scenarios BL, M3CC, C2 and C3. C3 has consistently decreased erosion compared to the other scenarios.

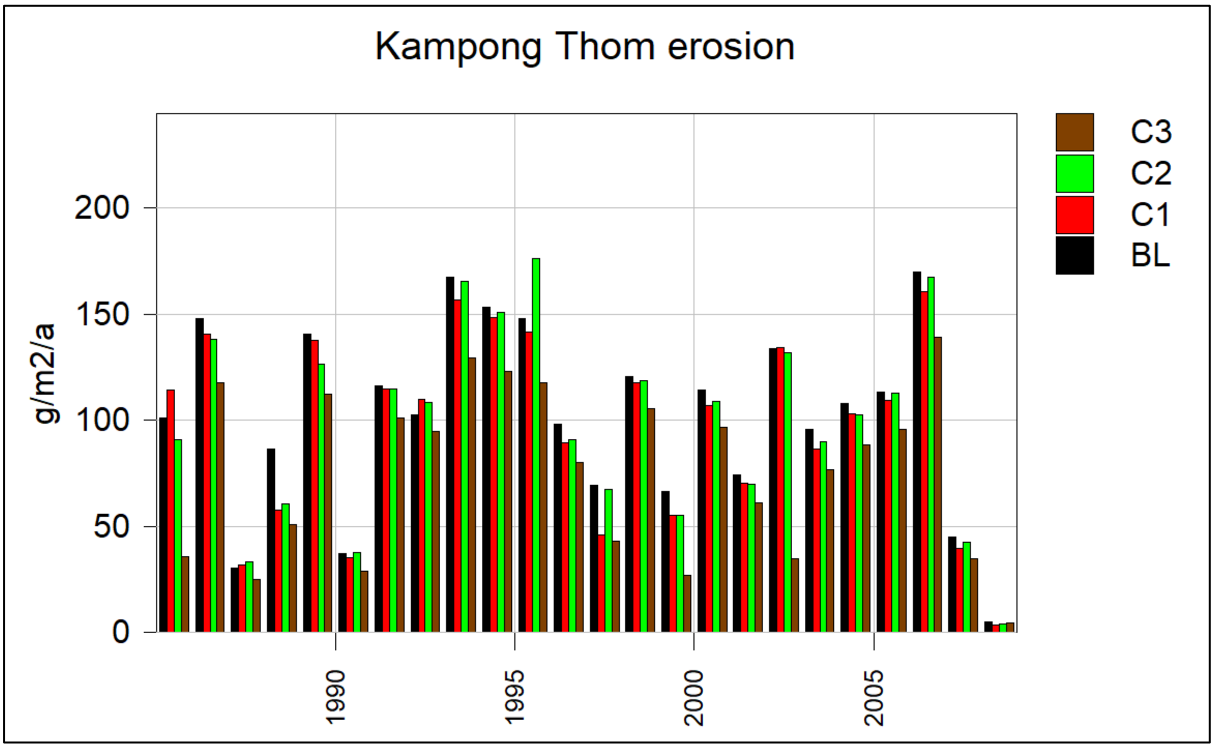


Figure 69. Kampong Thom annual agricultural area erosion for the climate scenarios BL, C1 (M3CC), C2 and C3.

Kampong Thom non-irrigated rice production is shown in Figure 70. The production shows rice failure for the years 1987, 1990 and 2008. Overall the climate scenarios C1, C2 and C3 have decreasing effect on production but the decrease is pronounced for C3. In the scenarios rice is planted mid-June.

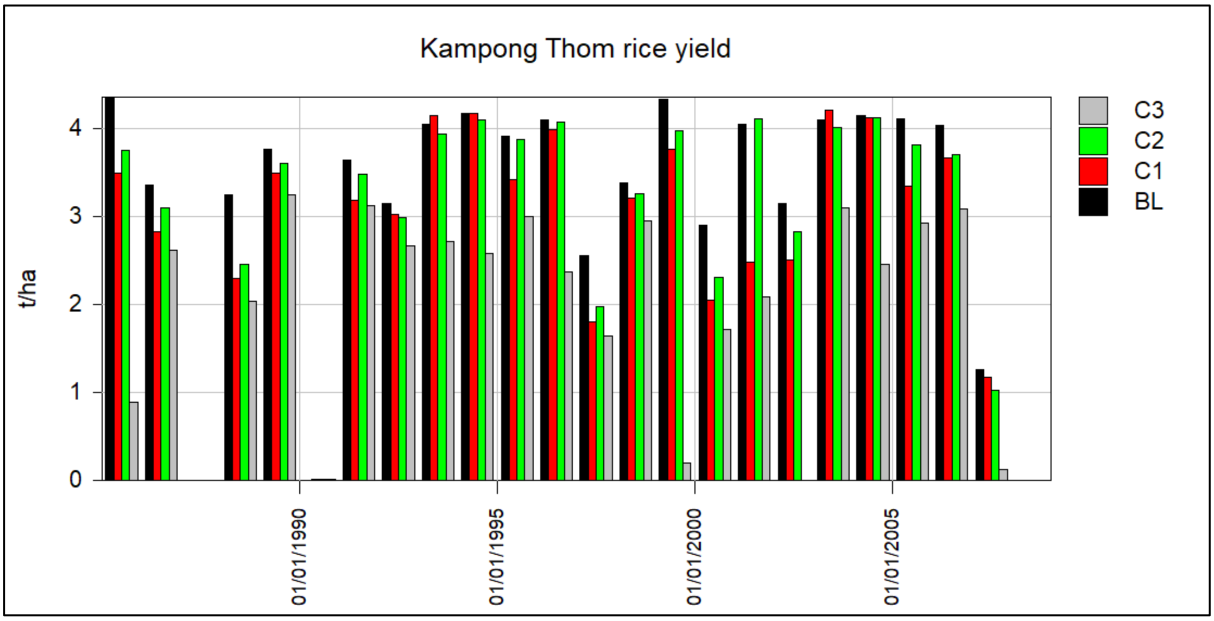


Figure 70. Kampong Thom rice production for the climate scenarios BL, C1 (M3CC), C2 and C3.

Figure 71 shows map of average non-irrigated rice production. The production decrease is pronounced and most critical in the South-Western part of the basin. This is because the area is already drier in the baseline conditions and will receive less rain in the future.

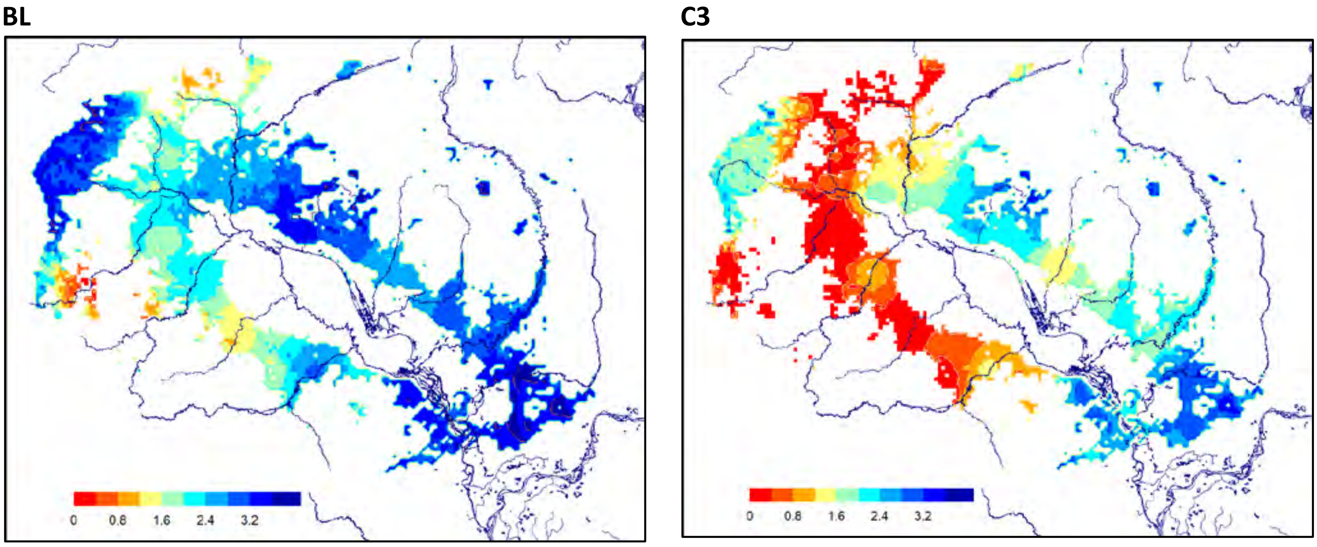


Figure 71. Average non-irrigated rice yields for mid-June planting.

18 Agriculture and land use development socio-economic consequences

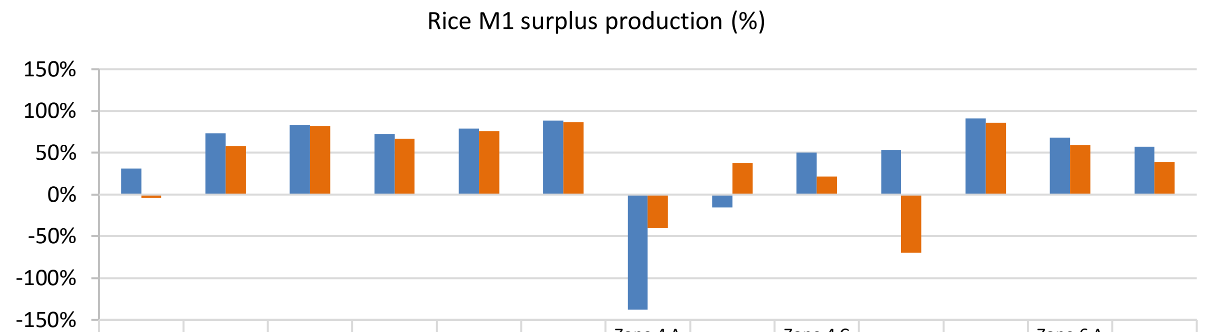
Food Security: Agricultural production and food consumption

It needs to be noted that the food security analysis in this chapter relates to the SIMVA-zones only. This is especially important for the upstream Kratie part where the SIMVA-zones cover only narrow 15 km corridor around the Mekong and are sensitive for hydropower development impacts. The total national rice production is expected to have surplus for all of the countries and for all of the years in the future (Ward, 2017).

18.1 Baseline (M1) food surpluses

Note that the rice production in the 4 A and 4 B and 4C Cambodian zones are primarily rainfed production and varied by up to 140% in response to the variance in modelled yields and the area of hectares suitable for cultivation.

Figure 72 Rice: surplus production after food security met: M1 years 1 and 24 by corridor zones. (ref. Socio-economic Assessment Report)



	Zone 2- Mainstream - Lao	Zone 3 A - Lao - Mainstream	Zone 2 B- Upper Thailand	Zone 2 C- Lower Thailand	Zone 3 B Thailand- Mainstream	Zone 3 C Thailand- Songkhram	Zone 4 A Cambodia -Khone Falls to Kratie	Zone 4 B Cambodia -3S	Zone 4 C Cambodia Kratie to Viet Nam border	Zone 5 A Cambodia -Tonle Sap river	Zone 5 B Cambodia Tonle Sap lake	Zone 6 A VietNam Delta - freshwater	Zone 6 B VietNam Delta - saline
M1 - 1	31%	73%	84%	72%	79%	89%	-138%	-16%	51%	53%	91%	68%	57%
M1 - 24	-4%	58%	82%	67%	76%	87%	-40%	37%	21%	-69%	86%	59%	39%

Main development scenario food surpluses compared to the M1 baseline

Differences between the M1 and main development scenarios revealed by the food security calculations and estimates are an indication of the main development scenario effects on fish and rice production and subsequent effects on food security.

The ratio of rice surplus (excess to meeting food security) to total production for the four main scenarios across the 13 corridor zones is summarized in Figure 74 and detailed in and Table 23. The percentage changes in fish and rice production, surplus to meeting food security needs, between the M1 baseline and the three main development scenarios (M2, M3 and M3CC) are detailed in Table 24.

Compared to the M1 baseline, the comparative aggregate increases in surplus rice production after meeting food security across all corridor zones were:

M1-M2= +6%

M1-M3 = +16%

M1-M3CC = +13%

Main findings for changes in rice production surpluses after food security needs met.

Cambodia: Rice

- Khone Falls to Kratie: The M2 rice production declines by 11% and increases by 40% (M3) and 51% (M3CC).
- 3S: rice production declines across all scenarios;
- Kratie to Vietnam Border: increases from 7% (M2) to 55% (M3CC);
- Tonle Sap River: declines from 61% (M2) to 150% (M3CC) compared to the M1 year 24 surplus;
- Tonle Sap Lake: stable production for M2 and M3, 4% increase estimated for scenario M3CC.

Lao PDR: Rice

- Upper Mainstream: substantial increases of up to 1083% (M3CC) due to rainfed and irrigation rice expansion
- Lower Mainstream: surpluses increase by up to 195% (M3CC).

Thailand: Rice

- Upper mainstream: rice production surplus to food security needs increase by 12% (M2), 29% (M3) and 18% (M3CC) due to mainly irrigation expansion;
- Lower Mainstream: rice production surplus to food security needs increase by 99% (M2), 143% (M3) and 133% (M3CC) due to mainly irrigation expansion;
- Mainstream: rice production surplus to food security needs increase by 49% (M2), 72% (M3) and 62% (M3CC);
- Songkhram: rice production surplus to food security needs declines by 4% (M2), 5% (M3) and 15% (M3CC);

Vietnam: Rice

- Rice surpluses in the freshwater zone of the Vietnam delta declined by 5% in M3 and 1% in M3CC; increased surpluses were predicted for the M3 (1%) and M3CC (16%) in the saline zone.

The spatial representation of the main development scenarios of rice surplus after meeting food security needs for each of the Corridor zones is illustrated in Figure 73. The maps represent the mean value (%) of years 1-24, year1 and year24.

The spatial representation of the development sub-scenarios of fish and rice surplus after meeting food security needs for each of the Corridor zones can be found in the Annex (. The maps represent the mean value (%) of years 1-24, year1 and year24 and the production ('000 tonnes) for the same time periods.

Figure 73 Rice surplus to meet food security needs: M1, M2, M3 and M3CC (% surplus to total production). (ref. Socio-economic Assessment Report)

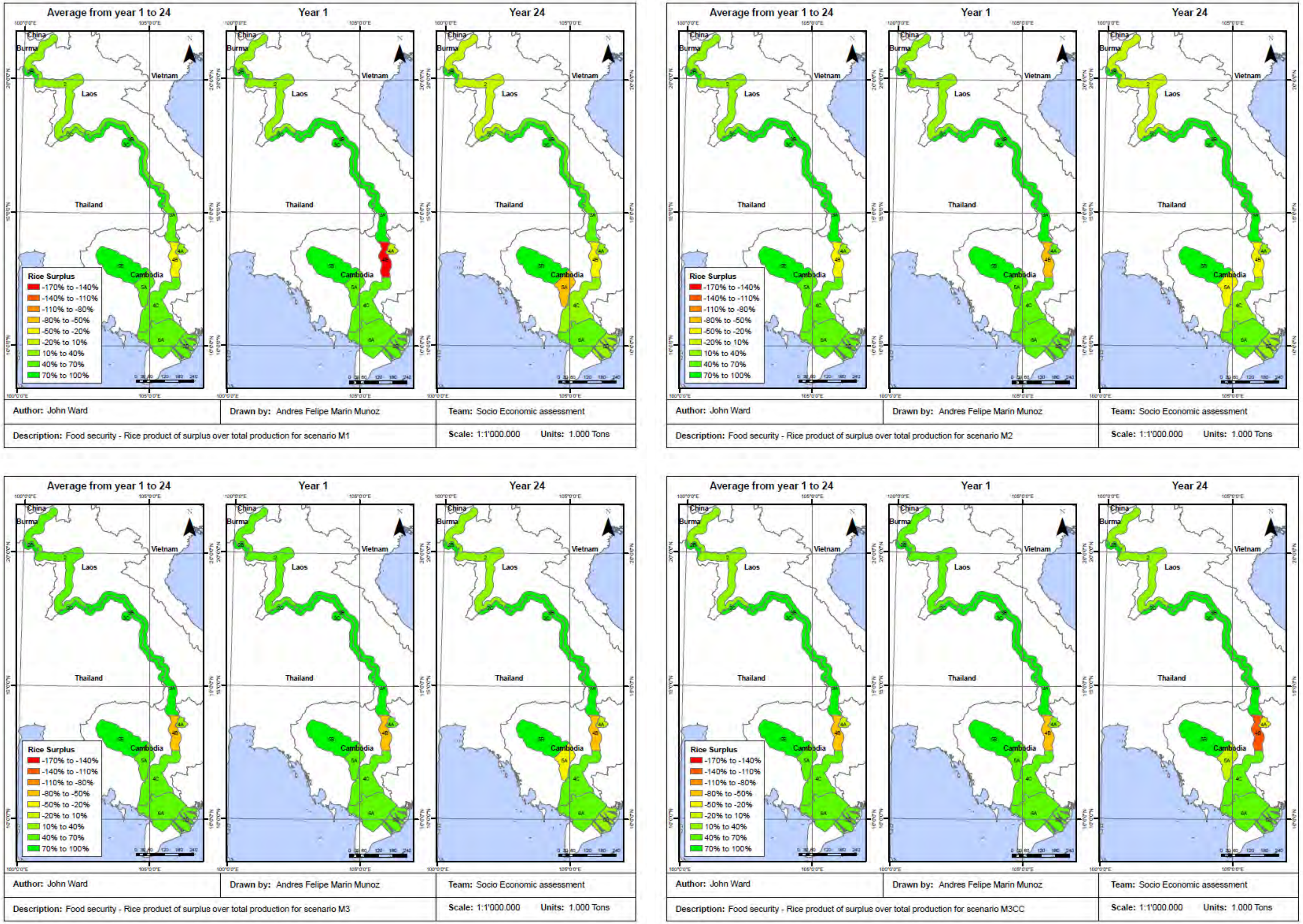
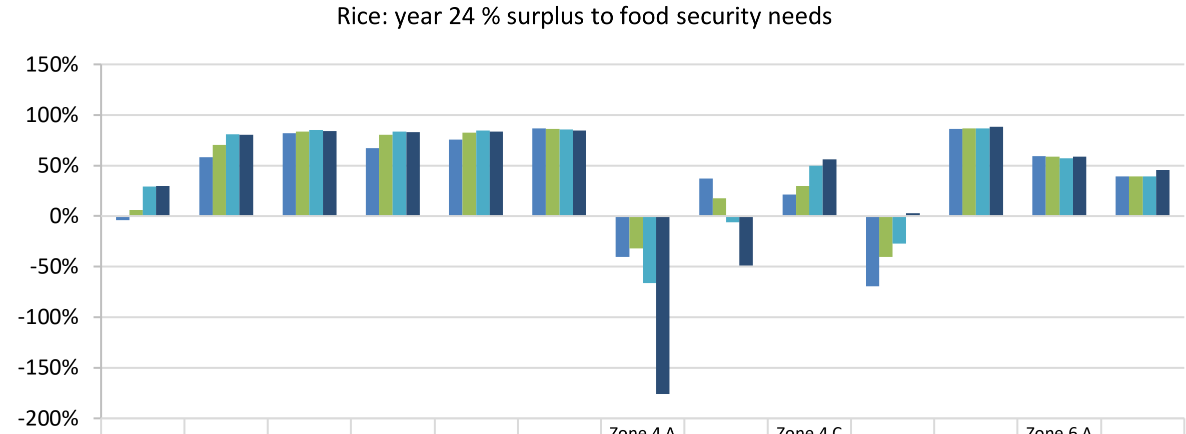


Figure 74 Rice production surplus to food security: M1-M3CC by corridor zones. (ref. Socio-economic Assessment Report)



	Zone 2-Mainstream - Lao	Zone 3 A - Lao - Mainstream	Zone 2 B-Upper Thailand	Zone 2 C-Lower Thailand	Zone 3 B Thailand-Mainstream	Zone 3 C Thailand-Songkhram	Zone 4 A Cambodia-Khone Falls to Kratie	Zone 4 B Cambodia-3S	Zone 4 C Cambodia Kratie to Viet Nam border	Zone 5 A Cambodia-Tonle Sap river	Zone 5 B Cambodia Tonle Sap lake	Zone 6 A VietNam Delta - freshwater	Zone 6 B VietNam Delta - saline
M1 - Rice	-4%	58%	82%	67%	76%	87%	-40%	37%	21%	-69%	86%	59%	39%
M2 - Rice	6%	70%	84%	80%	82%	86%	-32%	18%	30%	-40%	86%	59%	39%
M3 - Rice	29%	81%	85%	83%	84%	86%	-66%	-6%	50%	-27%	87%	57%	39%
CC - Rice	30%	80%	84%	83%	84%	85%	-176%	-49%	56%	3%	88%	59%	46%

Table 23 Corridor rice production and surplus (year 1-24). (ref. Socio-economic Assessment Report)

Rice	Mean annual production ('000 tonnes)				Mean annual surplus ('000 tonnes)			
SIMVA zones	M1	M2	M3	CC	M1	M2	M3	CC
Zone 2-Mainstream - Lao	98.1	110.6	144.7	133.6	17.7	30.3	62.8	51.3
Zone 3 A - Lao - Mainstream	468.7	624.0	961.3	929.7	309.0	463.3	800.6	768.2
Zone 2 B-Upper Thailand	67.5	74.2	83.0	75.5	56.2	62.8	71.6	64.2
Zone 2 C-Lower Thailand	36.0	60.0	70.5	68.5	24.7	48.6	59.2	57.2
Zone 3 B Thailand-Mainstream	425.7	552.5	617.5	593.4	330.4	457.4	522.1	497.8
Zone 3 C Thailand-Songkhram	78.6	76.2	75.1	73.6	67.3	64.9	63.7	62.2
Zone 4 A Cambodia-Khone Falls to Kratie	6.5	6.7	6.1	5.8	-2.7	-2.8	-4.0	-4.1
Zone 4 B Cambodia-3S	0.7	0.7	0.8	0.7	0.1	0.3	0.2	0.0
Zone 4 C Cambodia Kratie to Viet Nam border	1304.7	1411.4	1838.2	2047.1	555.5	654.6	1075.7	1286.1
Zone 5 A Cambodia-Tonle Sap river	404.8	452.3	479.4	535.5	179.9	220.5	242.5	298.9
Zone 5 B Cambodia Tonle Sap lake	1309.9	1340.8	1349.4	1476.7	1152.5	1183.6	1192.6	1319.0
Zone 6 A VietNam Delta - freshwater	3932.2	3853.1	3753.0	3830.6	2555.3	2479.6	2373.8	2449.9
Zone 6 B VietNam Delta - saline	1169.6	1168.0	1167.0	1192.2	602.2	601.9	602.3	623.2
Total	9303.1	9730.6	10545.9	10962.8	5848.1	6265.1	7063.0	7474.0

Table 24 % change in surplus available to meet food security, between development scenarios M1, M2, M3 and M3CC; year 24 by corridor zone. (ref. Socio-economic Assessment Report)

	Rice			Fish		
Corridor Zone	M1-M2	M1-M3	M1-M3CC	M1-M2	M1-M3	M1-M3CC
Zone 2 - Mainstream - Lao	70%	253%	189%	-91%	-101%	-92%
Zone 3 A - Lao - Mainstream	50%	159%	149%	-54%	-84%	-85%
Zone 2 B - Upper Thailand	12%	28%	14%	-33%	-68%	-73%
Zone 2 C - Lower Thailand	97%	140%	131%	-47%	-83%	-90%
Zone 3 B - Thailand - Mainstream	38%	58%	51%	-39%	-62%	-69%
Zone 3 C - Thailand - Songkhram	-4%	-5%	-8%	-36%	-57%	-63%
Zone 4 A - Cambodia - Khone Falls to Kratie	1%	1%	1%	-22%	-25%	-24%
Zone 4 B - Cambodia - 3S	1%	1%	1%	-1%	-44%	-45%
Zone 4 C - Cambodia - Kratie to Viet Nam border	4%	31%	27%	21%	38%	32%
Zone 5 A - Cambodia - Tonle Sap river	13%	21%	22%	-53%	-36%	32%
Zone 5 B - Cambodia - Tonle Sap lake	0%	0%	0%	-20%	-39%	-48%
Zone 6 A - Viet Nam - Mekong Delta - freshwater	0%	-4%	-5%	-11%	-12%	-13%
Zone 6 B - Viet Nam - Mekong Delta - saline	0%	0%	-4%	-27%	-30%	-29%
Overall change	6%	16%	13%	-32%	-46%	-44%

18.2 Annual variance in rice production

Comparing the values and state of the social and economic assessment indicators at the end of the 24-year projection horizon across the water development scenarios is a primary objective of the Council Study. The results of the Modelling team and BioRA indicate the corridor zones are subject to substantial annual variation in flows, sediment and nutrient flux in response to the development scenario conditions. Changes in flows and nutrient partially affects annual fish production and biomass and the potential yields for rice production.

The following section discusses the annual variance of rice production for each of the corridor zones in response to the conditions and factors associated with the four main development scenarios. The corridor zones were collated into country level graphics for ease of interpretation.

Cambodia

Rice:

Similar variance and acute deficits were estimated for rice production, albeit offset by increased and less variable rice production assumed to occur in the proposed irrigated rice expansion in the Kratie to the Vietnam Border zone. Note that Khone Falls and 3S zones have been omitted in Figure 75: rice production is relatively limited compared to the other Cambodian corridor zones.

Figure 75 Rice surplus to food security: annual variance, Cambodian corridor zones. (ref. Socio-economic Assessment Report)

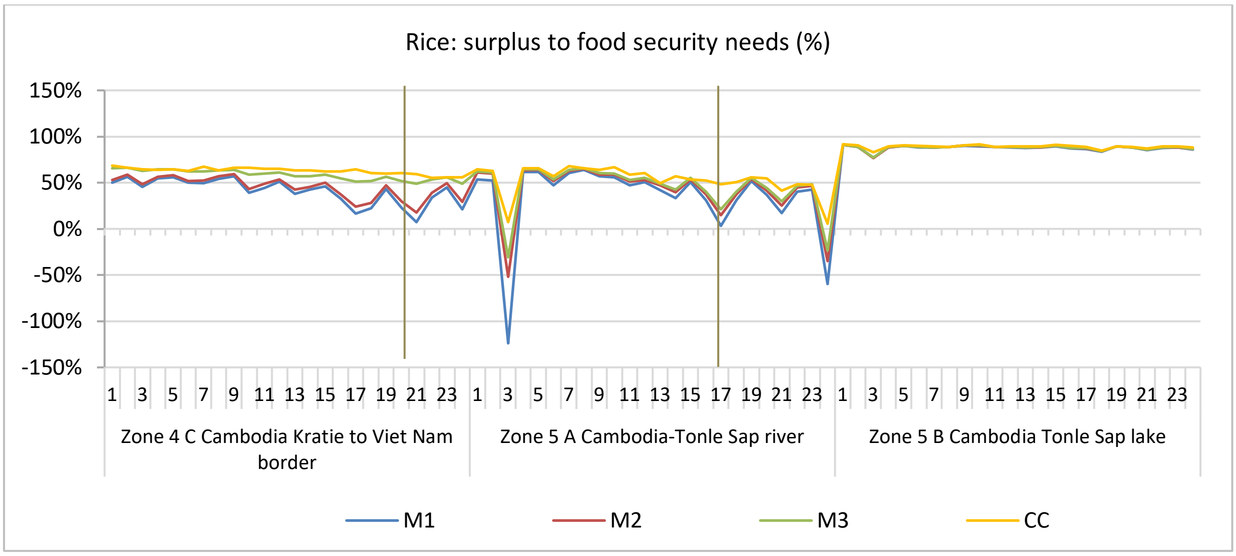


Table 25 %fish and rice production surplus to food security needs: by sub-scenarios (mean years1-24, *Year 24*). (ref. Socio-economic Assessment Report)

	Zone 4 C Kratie to Viet Nam				Zone 5 A -Tonle Sap river				Zone 5 B Tonle Sap lake			
	Fish		Rice		Fish		Rice		Fish		Rice	
Scenario	Mean 1-24	Yr 24	Mean 1-24	Yr 24	Mean 1-24	Yr 24	Mean 1-24	Yr 24	Mean 1-24	Yr 24	Mean 1-24	Yr 24
M3	34%	*28%*	58%	*49%*	5%	*-14%*	*45%*	*-23%*	57%	*55%*	88%	*87%*
CC	34%	*29%*	63%	*56%*	10%	*12%*	*53%*	*6%*	53%	*49%*	89%	*88%*
C2	34%	*29%*	57%	*42%*	14%	*-20%*	*47%*	*-31%*	58%	*54%*	88%	*86%*
C3	32%	*25%*	57%	*43%*	5%	*-27%*	*47%*	*-32%*	32%	*24%*	88%	*86%*
A1	35%	*29%*	39%	*22%*	4%	*-54%*	*38%*	*-71%*	53%	*50%*	88%	*86%*
A2	34%	*29%*	57%	*42%*	6%	*-16%*	*47%*	*-31%*	53%	*54%*	88%	*86%*
I1	38%	*33%*	57%	*42%*	8%	*-14%*	*47%*	*-31%*	56%	*57%*	88%	*86%*
I2	35%	*30%*	57%	*43%*	8%	*-15%*	*47%*	*-32%*	55%	*56%*	88%	*86%*
F1	34%	*29%*	58%	*49%*	12%	*13%*	*50%*	*-4%*	55%	*55%*	88%	*87%*
F2	34%	*29%*	59%	*50%*	9%	*6%*	*48%*	*-7%*	60%	*60%*	88%	*87%*
F3	34%	*29%*	58%	*49%*	26%	*19%*	*46%*	*-10%*	60%	*61%*	88%	*87%*
H1a	33%	*36%*	59%	*51%*	43%	*42%*	*47%*	*-7%*	68%	*68%*	88%	*87%*
H1b	27%	*27%*	58%	*50%*	32%	*33%*	*48%*	*-6%*	60%	*62%*	88%	*87%*
H3	36%	*30%*	58%	*50%*	27%	*25%*	*47%*	*-8%*	57%	*59%*	88%	*87%*

Lao PDR
Rice:
Rice production and irrigation expansion is estimated to increase across the Lao PDR zones: inter-annual variance is less in the M2-M3CC scenarios mainly due to the increased predictability of irrigated rice paddy. There is a minor increase in rice surplus due to climate change related effects in the upper mainstream zone and no detectable difference between the M3 and M3CC scenarios in Zone 3A mainstream.

Figure 76 Rice surplus to food security: annual variance, Lao PDR corridor zones. (ref. Socio-economic Assessment Report)

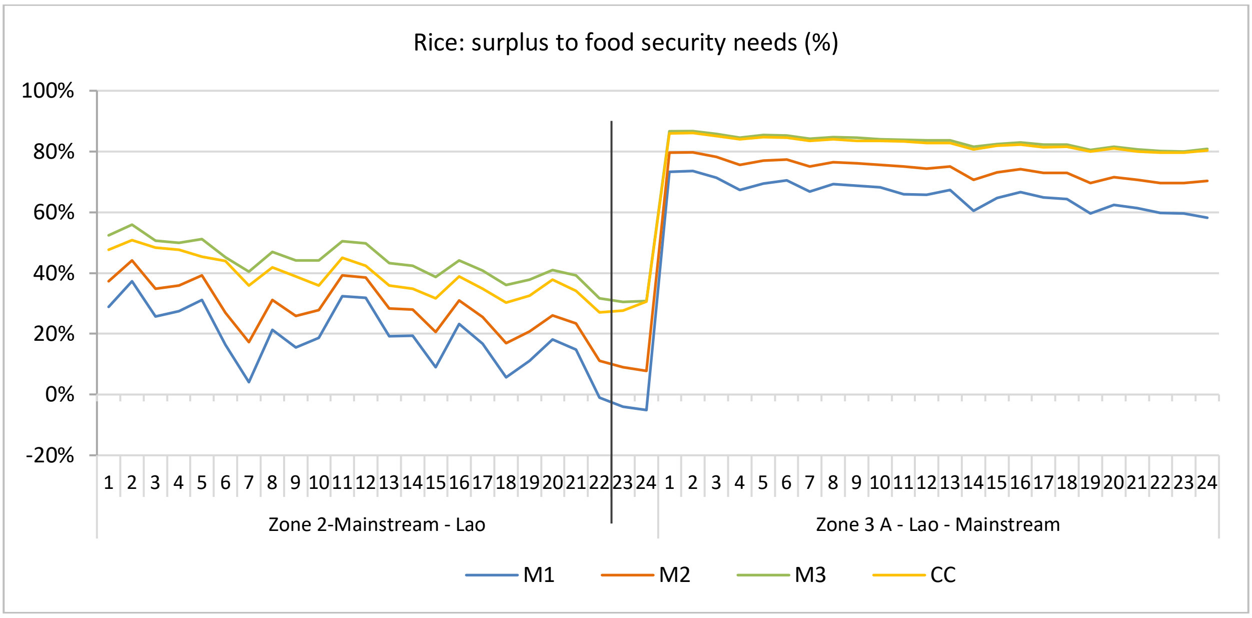


Table 26 % fish and rice production surplus to food security needs: by sub-scenarios (mean years1-24, *Year 24*). (ref. Socio-economic Assessment Report)

	Zone 2-Mainstream – Lao PDR				Zone 3A-Mainstream - Lao PDR			
	Fish		Rice		Fish		Rice	
Scenario	Mean 1-24	Yr 24	Mean 1-24	Yr 24	Mean 1-24	Yr 24	Mean 1-24	Yr 24
M3	-1%	*-1%*	43%	*31%*	11%	*10%*	83%	*81%*
CC	9%	*1%*	38%	*31%*	14%	*5%*	83%	*80%*
C2	18%	*-1%*	38%	*30%*	20%	*5%*	82%	*80%*
C3	8%	*23%*	36%	*27%*	12%	*6%*	82%	*80%*
A1	33%	*17%*	14%	*-10%*	33%	*23%*	64%	*59%*
A2	31%	*22%*	42%	*30%*	30%	*21%*	83%	*81%*
I1	35%	*19%*	43%	*30%*	32%	*21%*	83%	*81%*
I2	32%	*19%*	43%	*30%*	31%	*20%*	83%	*81%*
F1	33%	*18%*	38%	*31%*	31%	*19%*	82%	*80%*
F2	32%	*19%*	37%	*30%*	30%	*18%*	82%	*80%*
F3	32%	*74%*	37%	*30%*	30%	*18%*	82%	*80%*
H1a	76%	*68%*	38%	*31%*	64%	*62%*	83%	*80%*
H1b	72%	*24%*	38%	*31%*	54%	*48%*	83%	*81%*
H3	36%	*-1%*	37%	*30%*	32%	*22%*	82%	*80%*

Thailand:
Rice:
Rice production in Zone 2C and 3B increases with the proposed M2 and M3 expansion of paddi and conversion of rainfed areas to irrigated land. The oberved varaince of rice production in Zone 3C is a function of climate related effects on rainfed rice cultivation. There is limited irrigation in the Zone across all development scenarios. The M3CC scenario introduces decreases in the surplus rice available after meeting food security needs acorss all Zones.

Figure 77 Rice surplus to food security: annual variance, Thai corridor zones. (ref. Socio-economic Assessment Report)

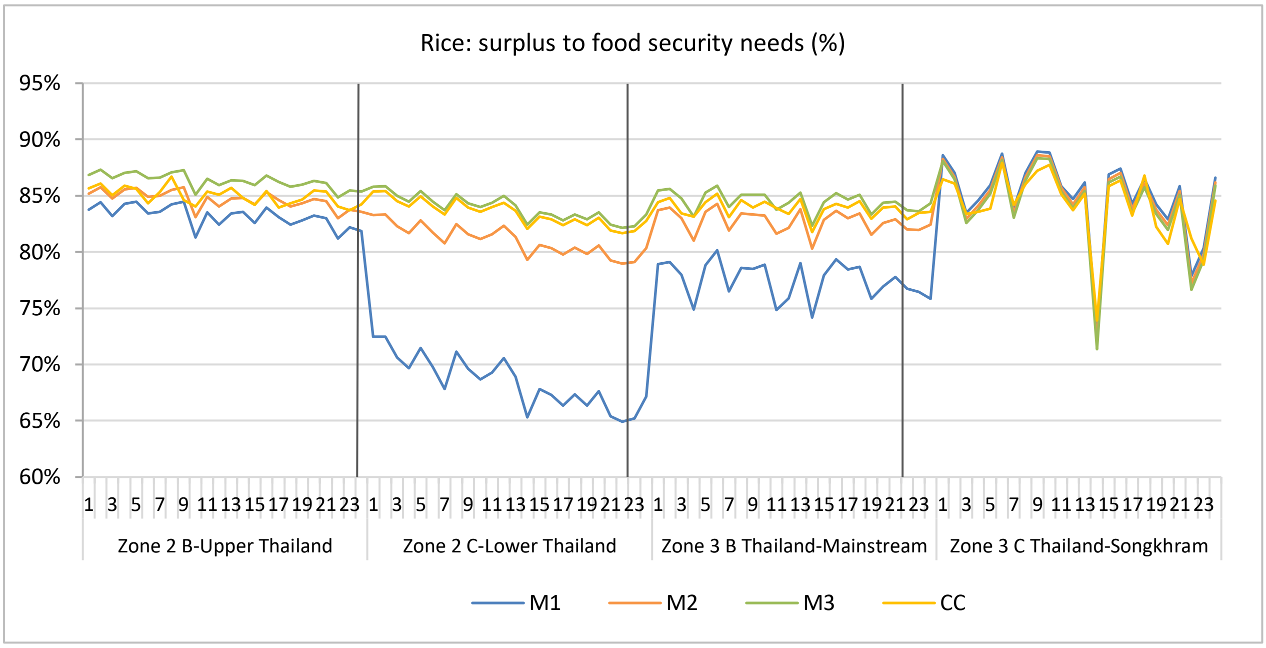


Table 27 % fish and rice production surplus to food security needs: by sub-scenarios (mean years 1-24; Year 24). (ref. Socio-economic Assessment Report)

	Zone 2B Thailand				Zone 2C Thailand				Zone 3B Thailand				Zone 3C Thailand			
Scenario	Fish		Rice		Fish		Rice		Fish		Rice		Fish		Rice	
	Mean	*Y 24*	Mean	*Y 24*	Mean	*Y 24*	Mean	*Y 24*	Mean	*Y 24*	Mean	*Y 24*	Mean	*Y 24*	Mean	*Y 24*
M3	43%	*39%*	86%	*85%*	84%	*24%*	56%	*83%*	85%	*46%*	64%	*84%*	84%	*62%*	74%	*86%*
CC	42%	*37%*	85%	*84%*	83%	*20%*	54%	*83%*	84%	*40%*	62%	*84%*	84%	*56%*	72%	*85%*
C2	44%	*40%*	85%	*84%*	83%	*20%*	54%	*82%*	84%	*41%*	62%	*83%*	84%	*57%*	72%	*85%*
C3	41%	*36%*	84%	*84%*	83%	*12%*	50%	*83%*	84%	*34%*	59%	*83%*	82%	*50%*	69%	*83%*
A1	41%	*37%*	83%	*82%*	68%	*22%*	47%	*67%*	78%	*43%*	60%	*77%*	85%	*59%*	73%	*87%*
A2	42%	*37%*	86%	*85%*	84%	*19%*	53%	*83%*	84%	*42%*	62%	*84%*	84%	*58%*	72%	*86%*
I1	42%	*37%*	86%	*85%*	84%	*21%*	54%	*83%*	84%	*42%*	63%	*84%*	84%	*58%*	73%	*86%*
I2	41%	*37%*	86%	*85%*	84%	*19%*	53%	*83%*	84%	*42%*	63%	*84%*	84%	*58%*	72%	*86%*
F1	41%	*37%*	85%	*84%*	83%	*19%*	53%	*83%*	84%	*41%*	62%	*84%*	84%	*57%*	72%	*85%*
F2	42%	*37%*	85%	*84%*	83%	*19%*	53%	*83%*	84%	*40%*	62%	*84%*	84%	*56%*	72%	*85%*
F3	42%	*37%*	85%	*84%*	83%	*19%*	53%	*83%*	84%	*40%*	62%	*84%*	84%	*56%*	72%	*85%*
H1a	64%	*62%*	85%	*84%*	83%	*65%*	74%	*83%*	84%	*70%*	75%	*83%*	84%	*80%*	82%	*84%*
H1b	61%	*59%*	85%	*84%*	84%	*58%*	72%	*83%*	84%	*59%*	71%	*84%*	84%	*72%*	79%	*85%*
H3	41%	*37%*	85%	*84%*	83%	*22%*	55%	*83%*	84%	*43%*	63%	*84%*	84%	*58%*	73%	*85%*

Vietnam

Rice:

Water, land and infrastructure limits on the potential for irrigation expansion combined with changing rice production to upland crops and cash crops implies that rice production is anticipated to decline across the 24 year CS time horizon for the M1 scenario. The attributes of the M2, M3 and M3CC scenarios have a relatively negligible effect on the expected yields in the freshwater Zone 6A and 3%-10% in the saline Zone 6B a likely affect of less irrigated paddi in the latter. There are relatively minor variations ascribed to the M3CC scenario compared to the M3 development scenario.

Figure 78 Rice surplus to food security: annual variance, Viet Nam corridor zones. (ref. Socio-economic Assessment Report)

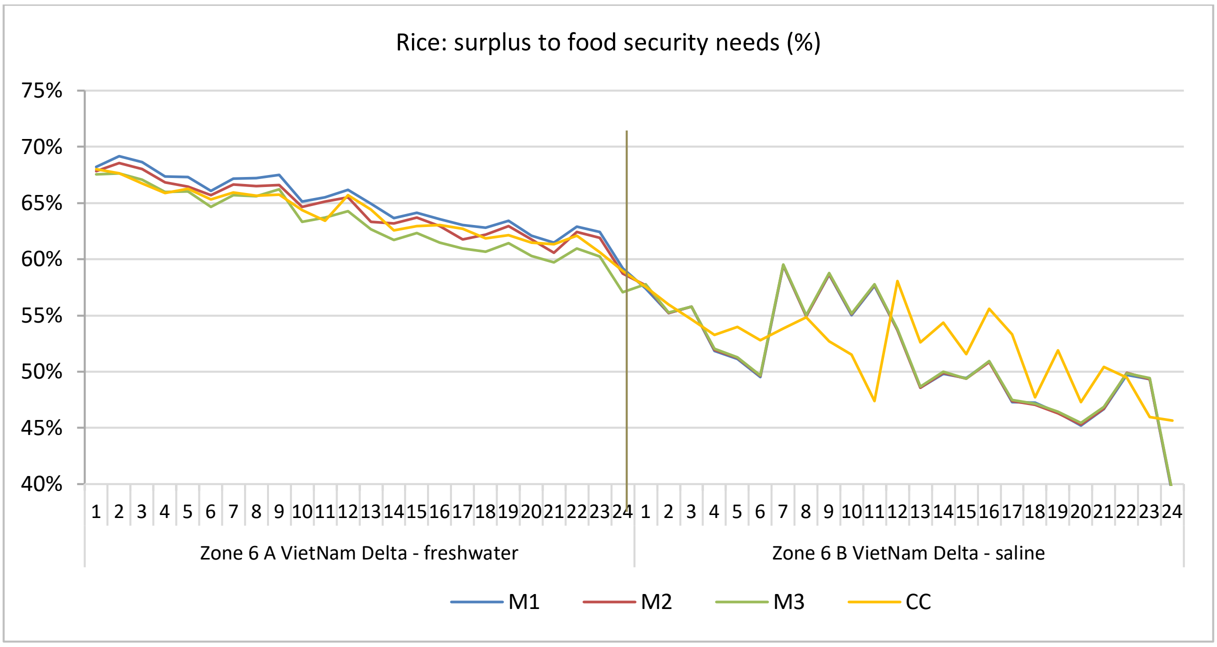


Table 28 % fish and rice production surplus to food security needs: by sub-scenarios (mean years1-24; *Year 24*). (ref. Socio-economic Assessment Report)

	Zone 6 A VietNam Delta - freshwater				Zone 6 B VietNam Delta - saline			
Scenario	Fish		Rice		Fish		Rice	
	Mean 1-24	*Year 24*	Mean 1-24	Year 24	Mean 1-24	Year 24	Mean 1-24	Year 24
M3	*61%*	*62%*	63%	*59%*	55%	*64%*	51%	*39%*
CC	63%	*60%*	64%	*59%*	62%	*60%*	52%	*39%*
C2	64%	*58%*	62%	*57%*	63%	*54%*	51%	*39%*
C3	62%	*60%*	63%	*59%*	60%	*60%*	51%	*46%*
A1	63%	*61%*	63%	*51%*	62%	*61%*	51%	*38%*
A2	63%	*60%*	62%	*51%*	61%	*58%*	51%	*38%*
I1	63%	*60%*	62%	*52%*	62%	*60%*	51%	*39%*
I2	63%	*60%*	63%	*51%*	62%	*59%*	51%	*38%*
F1	63%	*60%*	60%	*51%*	62%	*60%*	53%	*38%*
F2	62%	*60%*	60%	*51%*	58%	*60%*	52%	*38%*
F3	63%	*60%*	60%	*53%*	60%	*60%*	53%	*45%*
H1a	66%	*59%*	60%	*54%*	68%	*57%*	52%	*44%*
H1b	64%	*60%*	58%	*53%*	65%	*58%*	52%	*45%*
H3	63%	*63%*	63%	*54%*	61%	*65%*	52%	*44%*

19 Agriculture development macro-economic and ecological consequences

19.1 Macro-economic consequences

Four sub-scenarios have been considered for the assessment of impacts on the agricultural sector. The sub-scenario A1 assumes no expansion of agricultural activities beyond the situation of 2007. Table 29 indicates that if compared with scenario M3CC the net present value of agriculture in the lower Mekong Basin would be about $111.3 billion lower. This emphasises the relevance of the agricultural sector and the weight of investments in the current development plans. The above assessment of main-scenarios already pointed out that there is a likely negative angle to this dimension as it demands large parts of the workforce that would not be available to secondary and tertiary sectors, which typically grow faster than agriculture. This dimension will be further discussed below as this investment priority affects overall GDP growth (Smajgl, 2017).

Table 29: Economic benefit changes in % of agriculture sector income compared to M3CC. (ref. Socio-economic Assessment Report)

	A1 Difference		A2 Difference		I1 Difference		I2 Difference	
	B$	%	B$	%	B$	%	B$	%
Cambodia	-$70.0	-54.1%	+10.1	+7.8%	-$7.5	-5.8%	0.0	0.0%
Lao PDR	-$5.9	-12.3%	+15.3	+31.8%	-$5.9	-12.2%	+0.2	+0.5%
Thailand	-$9.9	-6.3%	0.0	0.0%	-$9.6	-6.1%	+2.4	+1.5%
Viet Nam	-$25.3	-20.2%	0.0	0.0%	$3.1	2.5%	0.0	0.0%
LMB	-$111.2	-24.1%	+25.4	+5.5%	-$19.8	-4.3%	+2.7	+0.6%

Sub-scenario A2 shows that the additional agricultural expansion would largely eventuate in Lao PDR and Cambodia and would facilitate an increase in net present value of $15.3 billion and $10.1 billion, respectively[1]. In relative terms this change is substantial for Lao PDR as it increases economic benefits derived from agriculture by nearly one third if compared with M3CC. However, these sector-specific advantages can create a macro-economic barrier to economic growth due to the labour demands, as previously mentioned.

19.2 Ecological consequences

To assess the impacts of agricultural landuse on the river ecosystem, different levels of agricultural landuse were evaluated in terms of their relative impact on the Mekong River ecosystem. Comparisons were made between 2040CC and two sub-scenarios with different levels of landuse, *viz*. (Table 30) (Brown, C. et al., 2017):

A1_noALU: 2040CC but with agricultural landuse at 2007 levels;
A2_ALU: 2040CC but with a higher level of agricultural landuse than that modelled in the 2040CC scenario.

Table 30: Sub-scenarios to test the effects different levels of agricultural landuse.

Scenario		Level of Development for water-related sectors						Climate
		ALU	DIW	FPI	HPP	IRR	NAV	
2040CC	Planned Development Scenario 2040CC	2040	2040	2040	2040	2040	2040	Mean warmer & wetter
A1_noALU	Planned Development 2040 without ALU	2007	2040	2040	2040	2040	2040	
A2_ALU	Planned Development 2040 with HIGH ALU	HIGH	2040	2040	2040	2040	2040	

The outputs for key BioRA summary indicators for the 2040CC and two agricultural landuse sub-scenarios relative to the 2007 Baseline scenario are shown in Figure 79. The differences in geomorphological conditions and habitat quality; vegetation; macroinvertebrates; fish; herpetofauna; birds, and; mammals in the unimpounded section of the river between 2040CC and the agricultural landuse sub-scenarios are illustrated in Figure 80. Importantly, these all incorporate the estimated 2040 floodplain protection

[1] Recent discussions in Cambodia instigated reforestation plans that target a forest cover of 48% (or 8.7 m ha), which would translate into an overall improvement of the average net present value of natural capital to +$93 billion (MIN: +$47 billion and MAX: +$138 billion)

infrastructure. The impacts on the ecosystem resulting from agricultural landuse change and floodplain protection are often similar, interconnected, and extremely difficult to separate. This means that the effects of agricultural landuse distinguishable using the agricultural landuse sub-scenarios are almost certainly underestimated as the assessment assumes that the differences in agricultural landuse between the sub-scenarios do not affect flooding.

The key BioRA summary indicators show that the predicted changes under the three scenarios are very similar (Figure 79), although not identical, which suggest that developments other than agricultural landuse are the drivers of ecosystem change predicted in the scenarios. This is possibly because much of the riparian zone had already been converted to agriculture by 2007, and/or because the effects of herbicide and pesticide use are not considered and/or because these do not distinguish the impacts of flood protection.

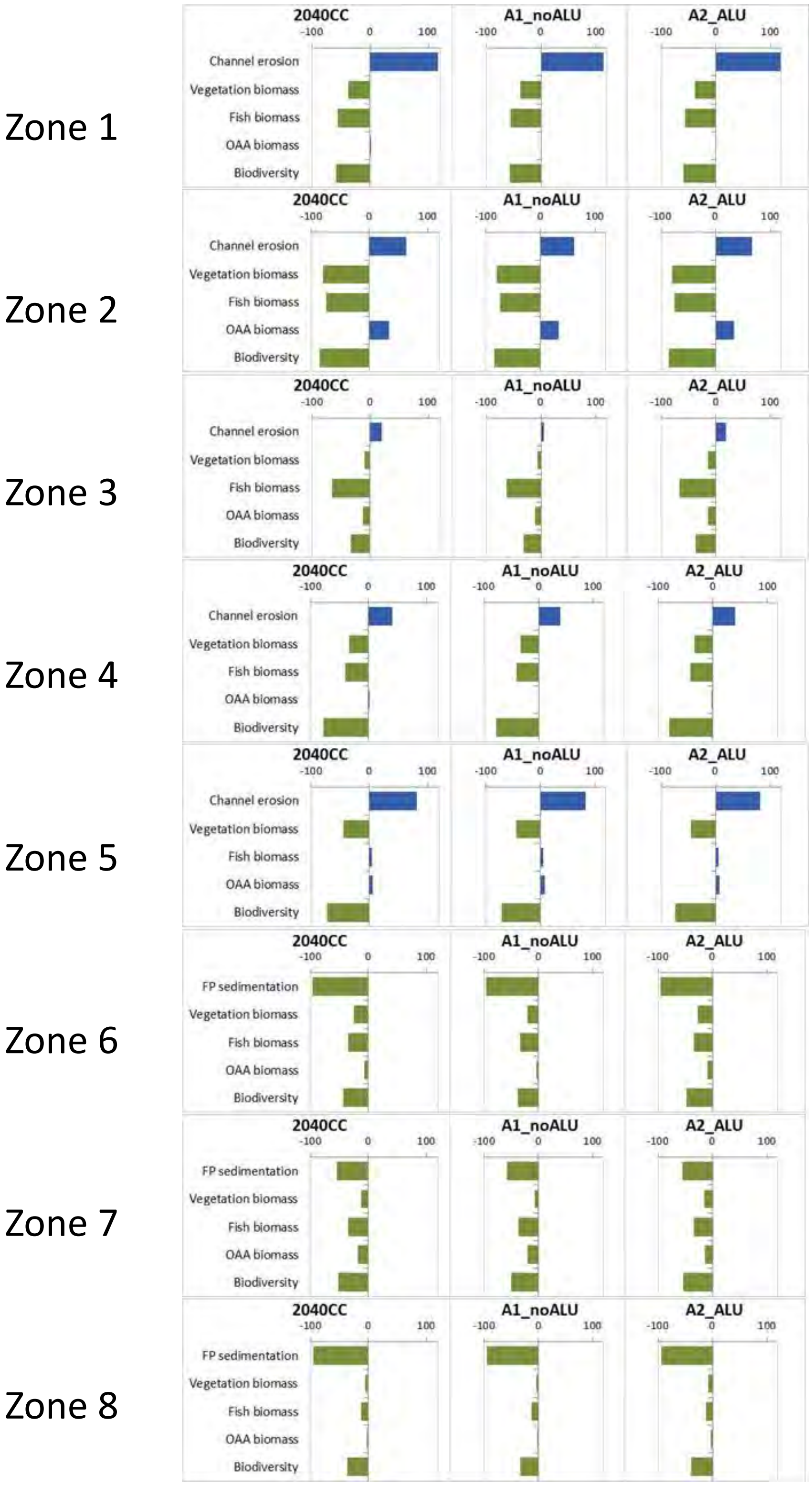


Figure 79. Predicted changes from 2007 Baseline in key ecosystem indicators for the BioRA zones for the agricultural landuse sub-scenarios (left to right): 2040CC, A1-noALU and A2_ALU. FP = floodplain; OAA = Other Aquatic Animals. (ref. BioRA Final Technical Report)

The incremental effects of the differences in the geomorphological conditions and habitat quality; vegetation; macroinvertebrates; fish; herpetofauna; birds, and; mammals in the unimpounded section of the river between 2040CC and the agricultural landuse sub-scenarios are shown in Figure 80, where blue bars denote a positive impact on ecosystem condition and red bars a negative impact on ecosystem condition.

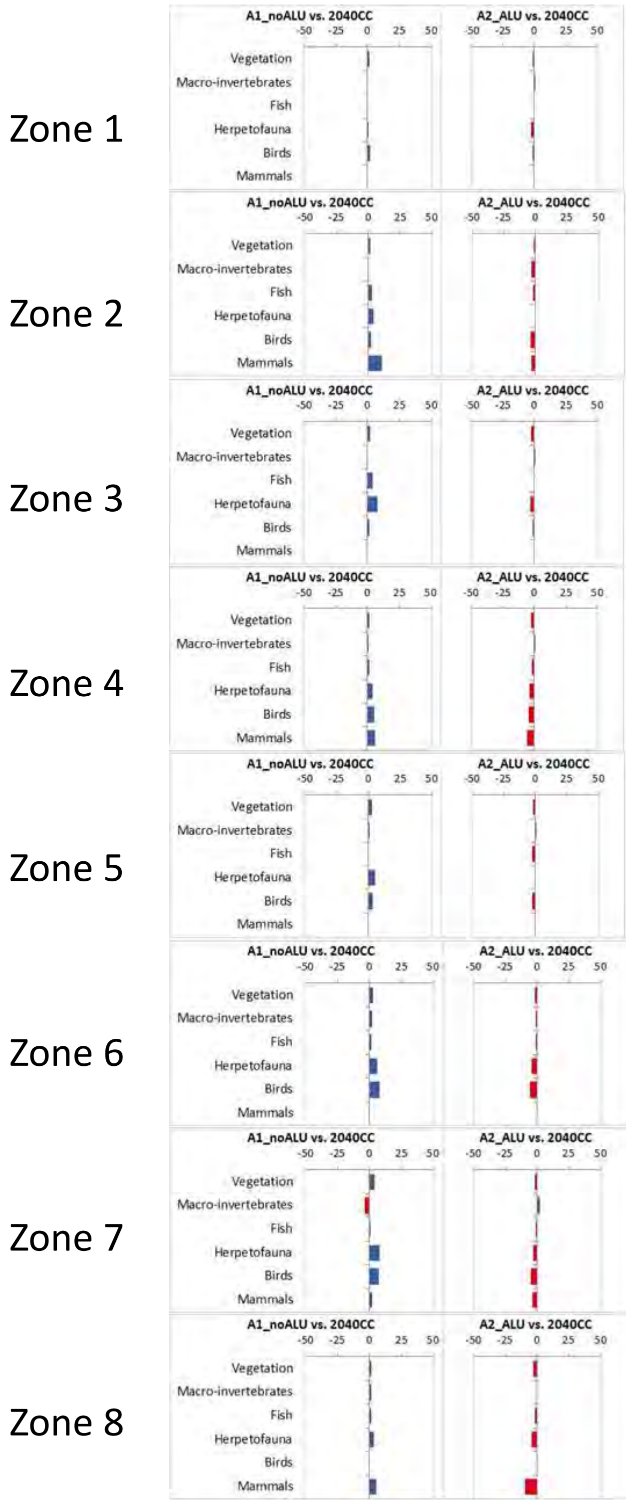


Figure 80. Difference in health for vegetation, macroinvertebrates, fish, herpetofauna, birds and mammals between 2040CC and the agricultural landuse sub-scenarios. (ref. BioRA Final Technical Report)

For the most part, reducing agricultural landuse to 2007 levels is predicted to result in slightly better ecosystem conditions relative to 2040CC (blue bars in Figure 80), even with all other developments at 2040 levels. Conversely, increasing the level of agricultural landuse above those in the Scenario 2040CC is expected to lead to slightly poorer ecosystem conditions relative to 2040CC (red bars in Figure 80). Under A2_ALU in Zone 6, the modelled duration of floodplain inundation is longer than for 2040CC, which favours some components of the ecosystem, e.g., the flooded forest and herbaceous march, and results in slightly better predicted conditions for A2_ALU.

While agricultural landuse developments undoubtedly do have an effect on aquatic ecosystems, both sets of results suggest that, in the context of the Council Study, impacts that may have been associated with changes in agricultural landuse are largely masked by the impacts of the other sector developments, especially hydropower, comprising Scenario 2040CC. This is particularly the case when the effects of herbicide and pesticide use are not considered.

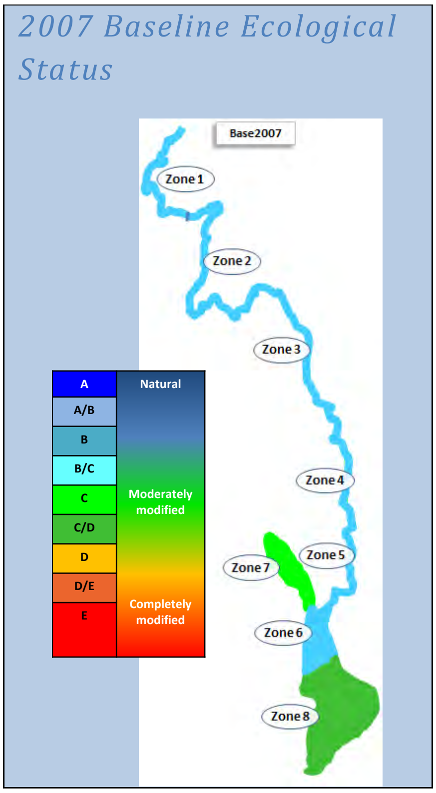


Figure 81. Estimated Baseline 2007 ecological conditions of the mainstream ecosystems the LMB. (ref. BioRA Final Technical Report)

The differences between Scenario 2040CC and the agricultural landuse sub-scenarios are insufficient to affect the predictions for overall ecosystem health except in Zone 8, where they translate into an increase in overall ecosystem health in the Delta (Zone 8) under A1-noALU (Figure 82). This is a small change relative to Scenario 2040, however, and in no way approaches the condition of Baseline 2007 (Figure 81.).

The ecosystem condition categories that result from increased agricultural landuse (A2_ALU) to levels higher than those included in Scenario 2040CC are similar to Scenario 2040CC (Figure 82).

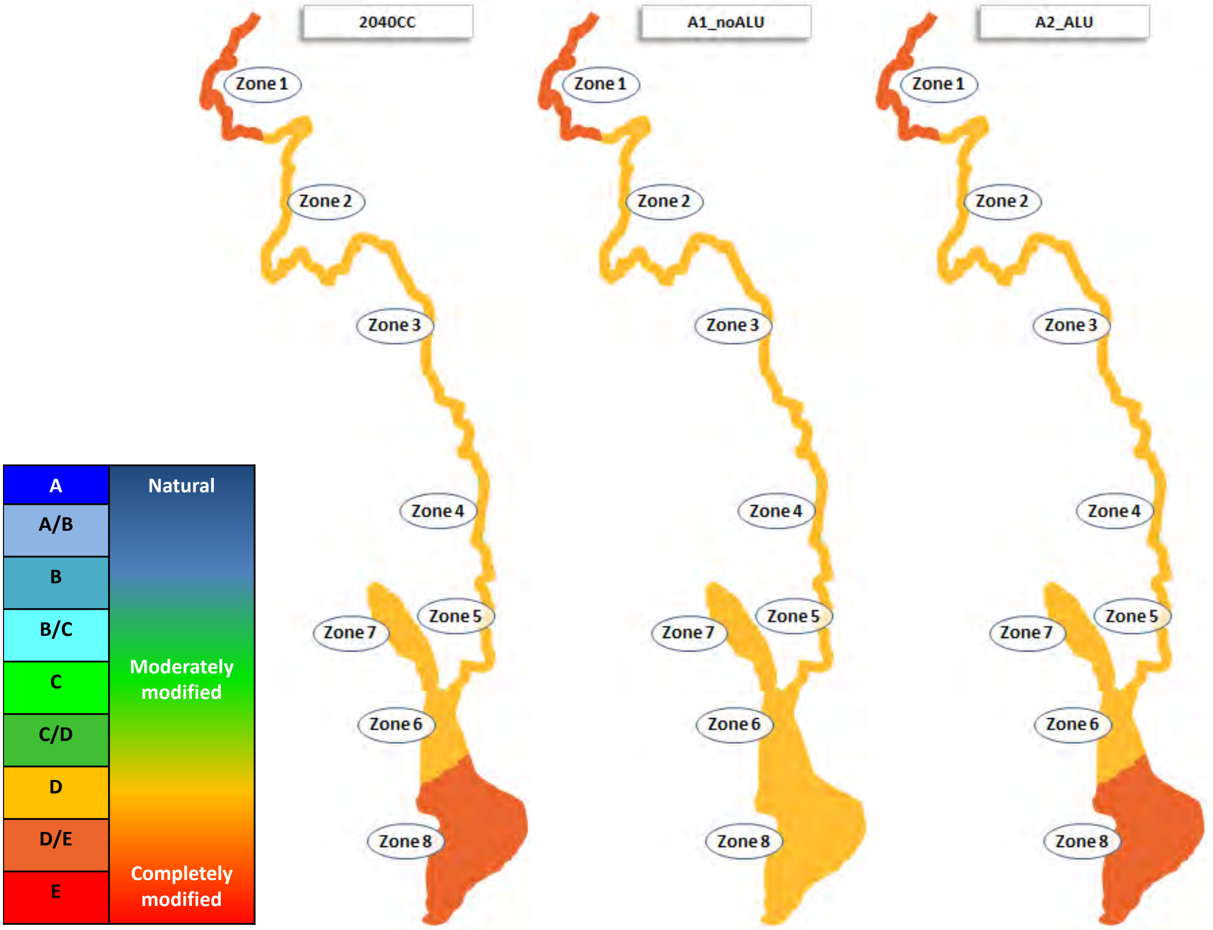


Figure 82. Mekong River condition predicted for the agricultural landuse sub-scenarios. (ref. BioRA Final Technical Report)

The key messages from the agricultural landuse sub-scenarios are:

- In the context of the Council Study, incremental hydrological-, hydraulic- and sediment-related impacts associated with agricultural landuse development are masked by the much greater impacts associated with the other sector developments comprising Scenario 2040CC.
- However, it was not possible to capture the full extent of some of impacts associated with agricultural landuse. For instance:
    - herbicide and pesticide use could have a devastating impact on the plants and animals at the base of the food chain in the LMB, but was not included in the assessment;
    - detailed and localised impacts associated with loss of habitat as a result of conversion to agricultural fields are not captured.

20 Study limitations and direction for future work

The Council Study has created of a fully integrated assessment framework from bio-geo-physical characteristics of the Mekong Basin reaching up to the policy level. The assessment methodology is ***evidence based and quantitative*** as the large economic, social and environmental values of the Mekong development require solid information basis. The assessment methodology is fully integrated as data and modelling are directly feeding into social, economic and environmental indicators and assessment and these in turn into the Thematic sectors. Other strong point of the Council Study is its thorough analysis of monitoring data, especially sediments and water quality, that has not been executed before. At the same time there are limitations involved with the study that stem from lacking data and broad scope of the exercise which constraints how far any specific discipline or thematic team has been able to pursue its sub-study.

The main limitations and constraints for the ALU **data** requiring improvement in the future can be summarized as:

- The land use change numbers they are based on best available information and estimates at the time of the project implementation but that they need to be updated based on latest national surveys, policies and plans.
- More detailed land use data should be made available. This applies especially to location and areas of mining, urban centers, irrigation and crop types. Especially areas of maize, sugarcane and cassava should be clarified.
- Crop calendars need to be checked;
- Information on agrochemical (nutrients, pesticides, herbicides) releases is almost non-existent;
- Data on rice paddy fisheries and aquaculture is lacking such as how much fish is produced and how different farming practices affect the fisheries;
- Climate scenarios need to be re-analyzed in order to capture ranges of possible future climates including more seasonal, drier, wetter and more variable climates.

The main limitations and constraints for the ALU **modelling** requiring improvement in the future can be summarized as:

- Upstream Kratie the detailed agriculture impact analysis has been conducted only in the narrow corridor around the Mekong mainstream including tributary floodplains affected by the Mekong; for the socio-economic analysis this corridor has been further restricted so that the floodplains are not included. This causes the analysis to be non-representative spatially and overly sensitive for water level changes in the mainstream such as caused by flood fluctuations and construction of the mainstream dams. The main related issue is that more detailed agriculture macro-economic analysis is not meaningful using the restricted corridor and the socio-economic analysis covers only communities in the immediate vicinity of the mainstream;

- Other crops than rice have not been modeled;
- Although nutrient loads from agriculture has been included in the SWAT model there has been no possibility to calibrate or verify them because lack of data;
- Crop modelling requires accurate daily local hydrological time series. The SWAT calibration has not been conducted on daily basis and there are anomalies in the hydrological indicators that need to be corrected.
- SWAT erosion and nutrient model requires evaluation and probably thorough development and revision.
- There should be much more emphasis on drought modelling than what has been implemented so far.
- No flood control data (dyke locations, dyke heights) has been available for the detailed agriculture modelling. This can over-emphasize flooding in the IWRM crop model although as much ISIS data has been used as practically possible.

The above constraints relate directly to the thematic analysis. Below some additional limitations and constraints for the ALU **thematic analysis** requiring improvement in the future are indicated:

- Systematic risk-based approach has not been exercised in the irrigation analysis. For instance crop failure probability analysis due to flooding and droughts although it is included in the modelling.
- Flood damages to agriculture areas have been analyzed in general terms only.
- Mitigation options such as increased fertilizer use to compensate reservoir sediment and nutrient trapping have not analyzed quantitatively.

The Member Countries have indicated that the Council Study technology needs to be transferred to the countries for their independent update and iteration of the assessment. For instance, the countries have indicated that there is need to run new scenarios and use different future development policies and assumptions. Because of this the Council Study has been designed to be flexible, transparent, repeatable and open-ended to accommodate improved data and assessment tools in the future. The importance of the Council Study Assessment Framework is not so much that it is definitive, perfect and without information gaps but that it provides consistent scientific evidence based practical methodology and knowledge base to support further studies and processes. It would be important not to lose this knowledge and to continue improving it. In the future MRCS and the Member Countries should integrate the Council Study knowledge and methodology in the existing frameworks and activities.

21 Key findings, mitigation measures and recommendations

Finding: The largest expected land use changes in the LMB will be paddy field area increase (+6% of total area) and deciduous forest decrease (-8%) by 2020. Built/urban areas will increase gradually through migration and population growth, but the area change will remain under 2% of total land area. These estimates should be not taken as definitive values because of land use classification is not harmonized between the Member Countries, land use statistics are lacking accuracy and future land use projections may not be realized. **Mitigation measures**: Countries should review agricultural area expansion policies in terms of their economic feasibility. Also, in the future available labor may not be available for farming work or could be utilized more profitable in other sectors. **Recommendations**: (i) land use classification needs to be harmonized, (ii) different data sources including remote sensing needs to be utilized to arrive more accurate status and historical trend analyzes, (iii) national policies and future plans need to be clarified with different national authorities.

21.1 Impacts of Development Scenarios **on** ALU

Finding: ***Hydropower development*** is partly beneficial for agriculture as it increases dry season flows, decreases salinity intrusion and decreases flood peaks in case of good operation. On the other hand hydropower decreases sediment and nutrient inputs to agricultural areas through sediment and nutrient trapping causing soil fertility to decline. Yield losses are up to 20% if sediments are not compensated by fertilizers and maintenance of soil structure with organic material. **Mitigation measures**: Sediment and nutrient trapping can be mitigated in the source at least partially by reservoir sediment management. In the receiving end soil management measures can be implemented including addition of nutrients and organic material to soil.

Finding: *Climate change* affects agricultural production and ranges of suitable crops through water availability, flooding, temperature, salinity intrusion and susceptibility to weeds, plant diseases and pests. Modelling results indicate large increase of yields through CO_2 fertilization but results have not been present as at the same time there is indication plants will be less resistant and more susceptible to pests and diseases. **Mitigation measures**: Climate change adaptation can be mitigated with building water storage capacity, changing crop calendars, changing crops, soil management to build plant resistance, genetic engineering etc. measures described widely. **Recommendations**: Special attention needs to be dedicated to obtain as realistic future climate projections as possible. It is important to focus climate variability including flood and drought events instead of monthly average scaling of precipitation and temperature.

Finding: Modelling results show significant decline of soil water in the Tonle Sap watershed and consequent large decline in rainfed agriculture yields for the *dry climate scenario C3*. Also required irrigation amounts would increase in scenario C3 up to 20%. **Recommendations and mitigation measures**: Planning and actions for water storage and maintaining food security need to be taken early enough.

Finding: Agricultural production changes under the *future scenarios* are very heterogeneous through the Mekong basin and for different scenarios. However, the larger areas behave more consistently and have in increasing production trend for future due to increasing agricultural area. The exception is Vietnam where agricultural area even declines. **Recommendations**: Economic viability, availability of labor and food security should be considered when planning for agricultural expansion.

21.2 Impacts **of** ALU on others

Finding: Upstream Kratie agricultural development will have only marginal impact on Mekong *flows and sediment loads* as the agriculture area experiences only small changes in the scenarios. It has not been possible to assess reliably fertilizer and agro-chemical use impacts with the current data and modelling. **Recommendations**: (i) It would be important to have better understanding of nutrient and agro-chemical loads from agriculture based on targeted monitoring and improved modelling. (ii) Impact of very large number of small irrigation water storages needs to be clarified. (iii) Accuracy of current modelling for paddy rice hydrology and loads needs to be assessed. (iv) Modelling needs to be applied to the Cambodian floodplains also as they will experience large agriculture expansion.

Finding: Deforestation into degraded lands has large impact on *erosion sand sediment loads* but small impact on flow. **Mitigation measures**: Sustainable (agro)forestry practices. **Recommendations**: (i) Although all of the Member Countries are aiming at maintaining or increasing forest areas implementation can be lagging and needs to be monitored. (ii) As the modelling has been demonstrative only further model validation and more realistic implementation needs to be conducted.

Finding: In terms of *food security*, Cambodia can face occasional ***local*** issues with food security related to rice production. Also, Lao food security is not strong for some areas because of population growth. **Mitigation measures**: Obvious measures include decreasing rice production, storage and transportation losses, making agriculture more efficient, curbing population growth, and most importantly subsidize and support the affected areas.

Finding: In terms of *ecological impacts*, agricultural development changes are masked by other developments that have much larger impact on flow, sediments and nutrients. However, herbicide and pesticide use as well as agriculture expansion ecological consequences have not been considered here.

Finding: *Agriculture sector economic value* for the Member Countries is very substantial. Also investments to agricultural sector seem to be well justified. However, there are caveats with work force being more productive in other sectors and assumptions about required investments.
Recommendations: Countries should not assume agriculture development to be easily achievable in the future and not necessarily profitable. Countries should have built more versatile economies to become more resilient.

22 Conclusions and recommendations for the future work

Land use change is potentially one of the main factors impacting natural conditions and people's livelihoods. The estimated agriculture changes in the upstream Kratie part of the basin are small and consequently have marginal impact on flow and sediment loads as well as ecological conditions. In contrast Cambodia is experiencing rapid expansion of agriculture but modelling other than for irrigation has not been applied there. Another information gap is involved with fertilizer and other agro-chemical use that needs to be filled in the future with monitoring and modelling data.

Food security will decrease in the future scenarios for some Lao PDR areas and for Cambodia. This is mostly because of population growth and can become acute for specific flood and drought events. Driest climate change scenario C3 needs to be highlighted here.

Hydropower development has by far the largest impact on agriculture through water availability, flow and flooding, salinity and fertile sediment input to the agricultural areas. The impacts are both positive and negative. The positive impacts include improved water availability, mitigation of flood peaks and flood damages, increased dry season flow and decreased salinity intrusion. The negative impacts include decreased fertile sediment input to the floodplains and fields that need to be mitigated.

Climate change has obvious risks involved especially if drier climate projections are realized. Modelling indicates that in the assessment corridor Tonle Sap surroundings are quite sensitive to drier climate.

Council Study Agriculture and Land Use Thematic Area has made substantial strides forward in terms of GIS data processing, scenario definitions and implementation and integrated methodology connecting the thematic work to the triple bottom line assessment and modelling. Technically Council Study Modelling Team has made a major contribution in developing methodologies and tools for land use data gap filling, GIS data improvement and setting up land use in modelling. The achievements include:

- Assessing land use development trends from historical data and data provided by the Member Countries
- Correcting GIS map errors for land use such as gaps in data
- Defining spatial land use changes based on country values based on existing land use, irrigation channels, terrain slopes etc.
- Defining land use changes for SWAT HRUs (Hydrological Response Units). The software is included under the IWRM WUP-FIN model.

These developments have enabled accurate modelling for land use classes as well as rice and fish production and results utilization in socio-economic and environmental assessments. The tools should be consolidated and brought to MRC and Member Country general use under the IMIAT (Integrated Mekong Impact Assessment Tool) and Council Study exit proposals.

Methodology to estimate hydrological impacts to wetlands has been developed but not yet verified. This should be tested as it could provide important information for wetland management.

The agriculture and irrigation methodology needs to be brought to general use, evaluation and update of the MRCS and the Member Countries. Number of further developments are required to increase applicability and reliability of the assessment including:

- Farming practices including crop calendars, irrigation, multiple crops, application of agro-chemicals etc. should be included in the modelling. This is not an issue for the Council Study model technology but supporting data needs to be obtained, ordered and implemented in the models.
- Land use scenarios need clarification and development as the Member Countries develop their policies.
- In climate change modelling more emphasis should be on extreme events (floods and droughts) as well general climate variability. So far only monthly average changes have been included in the study.
- Flood and drought risks and damages should be analyzed more rigorously than has been possible so far.
- Other crops than rice should be included in the study.
- Rice-fish potential should be examined.
- The scope of detailed crop modelling should be expanded from the impact corridor to the whole basin.
- Erosion, sediment, nutrient and agro-chemical modeling requires much more thorough approach than has been so far exercised under the Council Study as these are linked to the main development factors in the Mekong, that is hydropower reservoirs and their processes, land use change, agriculture and climate change.

ANNEX I: ALU Data Gap Filling Methodology

This chapter is copied obtained from the GAP Filling Report (Vonnarart, O. and Nguyen Dinh, D., 2017).

From data review and checking consistency of data, the approaches for gap filling and estimated change in year 2020 and 2040 are:

1. Analysis annual rate change (%) of land cover/land use from MRCS database (year 1993, 1997, 2003 and 2010)
2. Analysis annual rate change (%of Land Cover) Land use from 2007, 2020 and 2040 based on data from national database – MC (collected by Thematic team)
3. Forecast annual rated change (%) between year 2007, 2020 and 2040. This step will based on annual rate change from MC's data, however if the change cannot be estimated from MC's data, annual rated change using MRC database (no. 1) will be applied.
   Based on SWAT model was set up and calibrate based on landuse 2003, therefore landuse data from year 2003 will be represent for landuse year 2007.
4. Estimated area (Ha) for forest and agriculture for year 2003 (represent year 2007), 2020 and 2040

STEP 1: Changing of Land Cover/Land use from 1993, 1997, 2003 and 2010 from MRC database

Country	Land Cover Types	Area - Ha				Annual change in Percent (%)		
		Forest Cover 1993	Forest Cover 1997	Land cover 2003	Land cover 2010	1993 to 1997	1997 to 2003	2003 to 2010
Cambodia	Forest	9,325,763	9,250,933	8,303,852	6,939,094	-0.20%	-1.78%	-2.53%
	Agriculture	3,119,628	3,300,431	3,719,442	5,562,064	1.42%	2.01%	5.92%
Lao PDR	Forest	12,496,818	10,369,155	17,379,583	12,544,221	-4.56%	8.99%	-4.55%
	Agriculture	1,126,164	1,215,662	1,925,550	2,160,023	1.93%	7.97%	1.66%
Thailand	Forest	3,463,729	3,395,853	4,133,540	3,946,045	-0.49%	3.33%	-0.66%
	Agriculture	14,474,804	14,483,036	13,484,104	12,455,561	0.01%	-1.18%	-1.13%
Vitenam HighLand	Forest	1,912,241	1,889,388	1,976,453	1,698,986	-0.30%	0.75%	-2.14%
	Agriculture	587,864	623,237	464,262	1,435,881	1.47%	-4.79%	17.50%
Vitenam -Delta	Forest	244,976	262,973	227,666	243,374	1.79%	-2.37%	0.96%
	Agriculture	2,848,723	2,876,571	2,592,771	2,369,514	0.24%	-1.72%	-1.28%
Total LMB	Forest	27,234,355	24,942,574	58,866,883	57,772,092	-2.17%	15.39%	-0.27%
	Agriculture	22,157,182	22,498,937	22,186,129	23,983,042	0.38%	-0.23%	1.12%

Annual change calculate by ((Final value - Start value)^(1/number of year))-1)

STEP 2: Changing of Land use from 2007, 2020 and 2040 from National data collection

Country	Land Cover Types	Area - Ha			Annual change in Percent (%)	
		Land use 2007	Land use 2020	Land use 2040	2007 to 2020	2020 to 2040
Cambodia	Forest	*7,332,127*	*4,094,292*	-	-4.38%	
	Agriculture	*3,596,882*	*2,466,393*	*1,137,029*	-2.86%	-3.80%
Lao PDR (Whole Country)	Forest	15,297,704	15,642,051	-	0.17%	
	Agriculture	4,553,668	4,795,145	5,000,000	0.40%	0.21%
Thailand (8 Provinces)	Forest	1,914,286	1,922,993	1,928,797	0.03%	0.02%
	Agriculture	3,272,315	3,261,121	3,253,368	-0.03%	-0.01%
Vitenam -HighLand	Forest	3,098,051	2,937,352	-	-0.41%	
	Agriculture	1,598,329	1,702,296	-	0.49%	
Vitenam -Delta	Forest	292,253	258,409	281,866	-0.94%	0.44%
	Agriculture	-	-	-		

- = Information was not completed for all province

- Cambodia: data was not completed therefore cannot estimate annual change.
- Laos: annual change of Forest from year 2007 to 2020 increase 0.2% and annual change of agriculture from year 2007 to 2020 and 2020 to 2040 increase 0.4% and 0.2% respectively.
- Thailand (8 provinces along Mekong river): annual change of Forest from year 2007 to 2020 and 2020 to 2040 increase 0.03% and 0.02%. Annual change of agriculture from year 2007 to 2020 and 2020 to 2040 decrease 0.03% and 0.01% respectively.
- Vietnam (Highland): annual change of Forest from year 2007 to 2020 decrease 0.04% and annual change of agriculture from year 2007 to 2020 increase 0.5%. No data in year 2040
- Vietnam (Delta): annual change of Forest from year 2007 to 2020 decrease 0.9% and annual change from year 2020 to 2040 increase 0.5%. No data of agriculture in year 2040.

STEP 3: Forecast of Annual Change for year 2007, 2020 and 2040

Country	Land Cover Types	Annual rate change in Percent (%)		Assumption for using data	
		2007 - 2020	2020 - 2040	For year 2020 - 2020	For year 2040
Cambodia	Forest	-2.53% from 2003 -2016 0.00% from 2016 - 2020	0.00%	Use annual rate from LU change 2003 / 2010 (MRC database) from 2003-2016 (present year), then no change based on country policy	No more reduce of Forest based on country policy
	Agriculture	replace forest area	0.00%	Expand based on reducing of Forest area	Expand based on reducing of Forest area
Lao PDR	Forest	0.17%	0.17%	Use annual rate from LU change 2007 / 2020	Use annual rate from LU change 2007 / 2020
	Agriculture	0.40%	0.21%		Use annual rate from LU change 2020 / 2040
Thailand	Forest	0.03%	0.02%	Use annual rate from LU change 2007 / 2020	Use annual rate from LU change 2020 / 2040
	Agriculture	-0.03%	-0.01%		
Vitenam HighLand	Forest	-2.14% from 2003 -2010 -0.41% from 2010 -2020	0.00%	Use annual rate change from LU change 2003 / 2010 (MRC database) from 20032010 , then apply annual rate change based on country change 2007/2020	No more change, based on limited of area
	Agriculture	17.22% from 2003 -2010 0.49% from 2010 -2020	0.00%		
Vitenam Delta	Forest	-0.94%	0.44%	Use annual rate from LU change 2007 / 2020	Use annual rate from LU change 2020 / 2040
	Agriculture	-1.28%	0.00%		No more change in Agriculture area, based on limited of area

Lao PDR

annual rate change (%)	2003/2007 to 2020	2020 to 2040
Forest	0.17%	0.17%
Agriculture	0.40%	0.21

Thailand

annual rate change (%)	2003/2007 to 2020	2020 to 2040
Forest	0.03%	0.02%
Agriculture	-0.03%	-0.01

Vietnam (Highland)

annual rate change (%)	2003/2007 to 2020	2020 to 2040
Forest	-2.14%	no change
Agriculture	** apply 2 rate	no change
	(1) 2003-2010 use 17.5 %	
	(2) 2011-2020 use 0%	

Cambodia

annual rate change (%)	2003/2007 to 2020	2020 to 2040
Forest	** apply 2 rate	no change
	(1) 2003-2016 use -2.53 %	
	(2) 2017-2020; no change	
Agriculture	replace Forest area	no change

Vietnam (Delta)

annual rate change (%)	2003/2007 to 2020	2020 to 2040
Forest	-0.94%	0.44%
Agriculture	-1.28%	no change

Figure: Annual rate change calculation from member country data combine with MRC database

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