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REPORT

Upscaling of Flood-Based Agriculture in Mekong Delta in Viet Nam

Report

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Table of Contents

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Table of Tables

Table of Figures

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1 Introduction

In larger parts of the Mekong Delta in Viet Nam, high dikes have been constructed to control the flood waters. This has allowed the planting of rice and the growth of other crops throughout the flood season. Initially, this resulted in higher yields due to facilitating a third rice crop. On the longer term, however, rice yields tend to be negatively affected by the reduced influx of fine sediments and the accompanying nutrients into the fields and the subsequent reduction of re-fertilization. Furthermore, as a result of the absence of (longer term) inundation throughout the year, pest control requires additional measures.

Research has shown that triple rice systems have negative long-term effects, both environmental and economic[1]. Farmers in areas with dikes high enough for triple rice production incurred rising production costs over time. Production costs were 60-90% higher in high-dike, triple crop areas, than in low-dike double rice crop areas. Higher production costs are mainly the result of increased fertilizer and pesticide use. Example cases show that profitability of triple rice farming systems initially is almost 60% higher compared to double rice cropping systems. However, after about 15 years, this advantage disappears. Knowing this, triple crop farming should be avoided when focussing on long term sustainability and long term profitability. Alternative farming systems, such as rice combined with vegetables, fisheries, aquaculture or other flood-based typologies could offer more and other benefits than intensive rice monocultures. Importantly, these higher benefits can be obtained without the environmental costs and impact currently endured across the delta with triple rice cultivation in high dikes.

Another publication[2] demonstrates the financial impacts of the loss of the re-fertilisation effects of the influx of fine sediment due to high dike building and triple rice cropping. The publication discusses the importance of sediment in the deltaic social-ecological system and the emergent risks arising from conflicting long and short-term adaptation and agricultural development objectives.

Construction of low and especially high dikes separates the previously natural floodplains from the river. Subsequently, the hydraulic and sediment dynamics largely disappear. This negatively impacts the biodiversity in high dikes areas, it takes away the natural sedimentation processes and it decreases strongly the re-fertilization of the soils. Therefore, upscaling of flood-based agriculture systems and natural floodplain protection has been considered. This aims to achieve the following goals:

1. Improved farmer incomes over a longer period of time
2. Restored biodiversity
3. Sustainable delta management

In order to achieve these goals, it is important that the fields are inundated during the flood season for a sufficiently long period. Therefore, the flood levels need to be high enough to overtop the dikes, or sluice gates need to be available to inundate dike rings. Enabling the entrance of floods onto the fields brings the following benefits:

- Recharge of the groundwater resources;
- Longer term inundation as a natural pesticide and the flushing of alum and pollution like residual pesticides in the field;

[1] *Dung Duc Tran, Gerardo van Halsema, Petra J.G.J. Hellegers, Fulco Ludwig and Andrew Wyatt, 2018. Questioning triple rice intensification on the Vietnamese Mekong Delta floodplains: An environmental and economic analysis of current land-use trends and alternatives*

[2] *Alexander D. Chapman, Stephen E. Darby, Hoang M. Hong, Emma L. Tompkins and Tri P. D. Van, 2016. Adaptation and development trade-offs: fluvial sediment deposition and the sustainability of rice-cropping in An Giang Province, Mekong Delta*

- Transport of fine sediments into the fields for re-fertilization, especially during the first floods that contain a relatively high amount of sediment;
- Free passage for fish to move into and out of the inundated fields, providing more breeding places for some aquatic species;
- Deposit of sufficient sediment in floodplains to maintain the processes of delta growing. This means the land level increase due to sedimentation should on the longer term be larger than the lowering effect of sea level rise and land subsidence.

This project
World Wildlife Fund (WWF) aims to identify priority areas for upscaling of flood-based agriculture, riparian conditions and nature protection areas to improve the conditions for agricultural and habitat development in the Upper Mekong Delta in Vietnam. The geographical scope of the projects includes the inland provinces of Can Tho, Kien Giang, Hau Giang, An Giang, Tien Giang, Dong Thap and Long An.

The project has focused on the following tasks:

1. Mapping of potential for upscaling of flood-based agriculture and natural floodplain protection
2. Identification of interventions to support the desired transition

This document
This document discusses the current conditions in the upper Mekong Delta in Viet Nam as far as relevant for this study in Chapter 2. Chapter 3 introduces the approach for identifying suitable areas for upscaling of flood-based agriculture and natural floodplain protection. Subsequently, the mapping of suitable areas based on the flooding dynamics is presented in Chapter 4. In Chapter 5, the impacts of the reducing sediment content in the river system on the suitability are analysed. Chapter 6 provides some directions for next steps.

2 Current conditions

The current agricultural land use in the upper Mekong Delta is dominated by triple and double rice cropping. Figure 2-1 provides an overview of the cropping pattern mapped by Can Tho University (CTU) in 2017. This cropping pattern is still largely representative for the current agricultural land use.

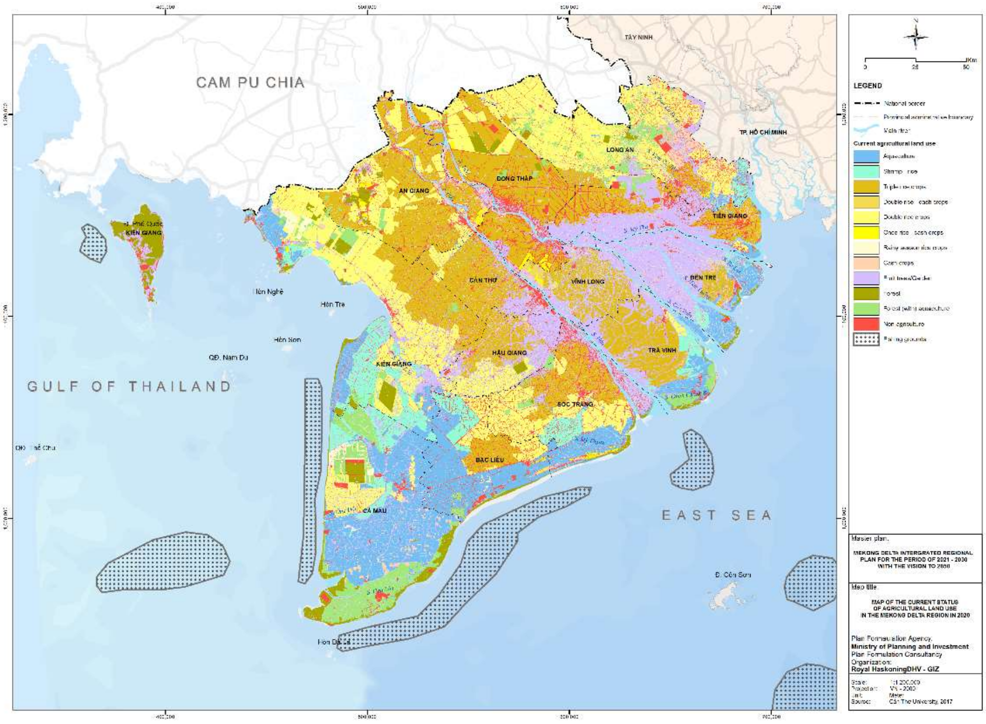


Figure 2-1 Current agricultural land use (CTU, 2017; MDIRP, 2022)

A dense network of canals has been constructed in the Mekong Delta over the past 150 years. These canals have both an irrigation and drainage function. Most larger canals also serve as navigation channels. Many of the main and secondary canals in the upper Mekong Delta are in open connecting with the Hau and Tien river, with exception of the area between both river branches north of Song Vam Nao. An overview of the main water management infrastructure – rivers and canals, river and sea dikes, and existing sluice gates – is shown in Figure 2-2.

The maximum flood inundation depth and extent maps for exceedance probabilities of 50% (return period 1 in 2 years), 10% (1/10yr) and 1% (1/100yr) are provided in respectively Figure 2-3, Figure 2-4 and Figure 2-5. The inundation patterns have been simulated with a detailed hydraulic model of the lower Mekong Basin. The simulations have been made with all existing high dikes in place, and assuming the predicted climate change and sea level rise for 2030.

Figure 2-2 Water management infrastructure – rivers and canals, river and sea dikes, and existing sluice gates in the Mekong Delta in Viet Nam (MDIRP, 2022)

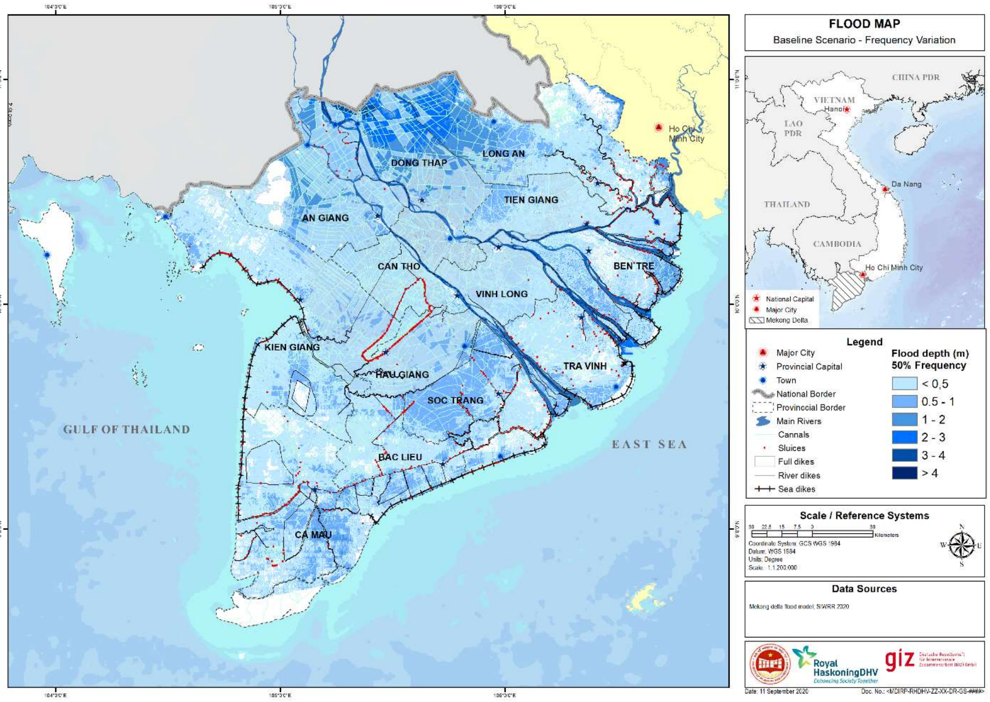


Figure 2-3 Maximum flood inundation depth and extent map for current infrastructure situation. Exceedance probability 50% (return period 1 in 2 years). Projection with climate change in 2030 (MDIRP, 2022)

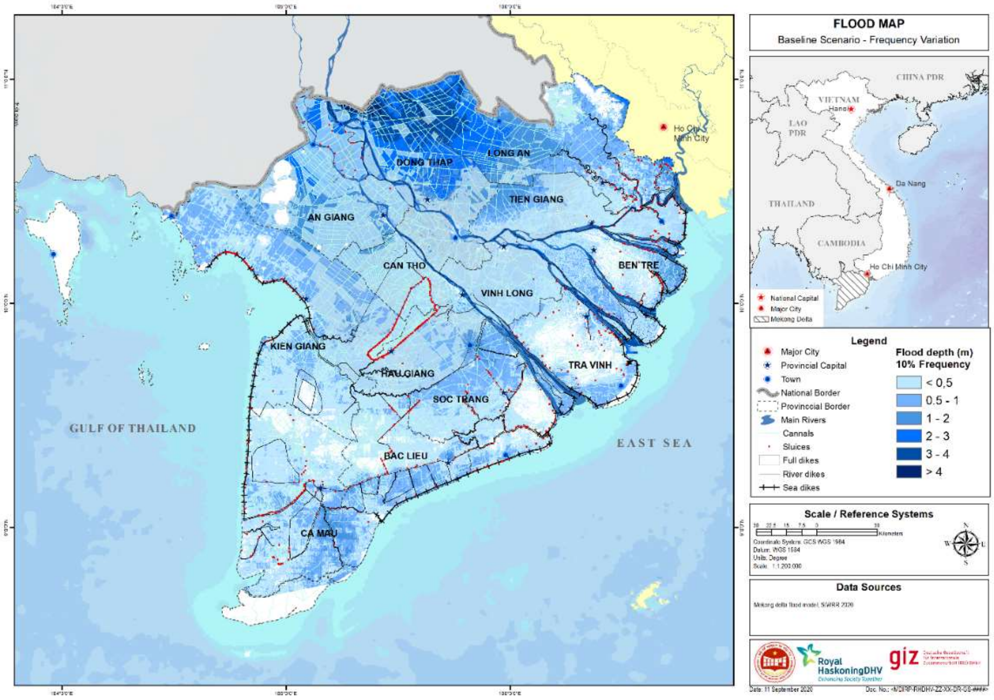


Figure 2-4 Maximum flood inundation depth and extent map for current infrastructure situation. Exceedance probability 10% (return period 1 in 10 years). Projection with climate change in 2030 (MDIRP, 2022)

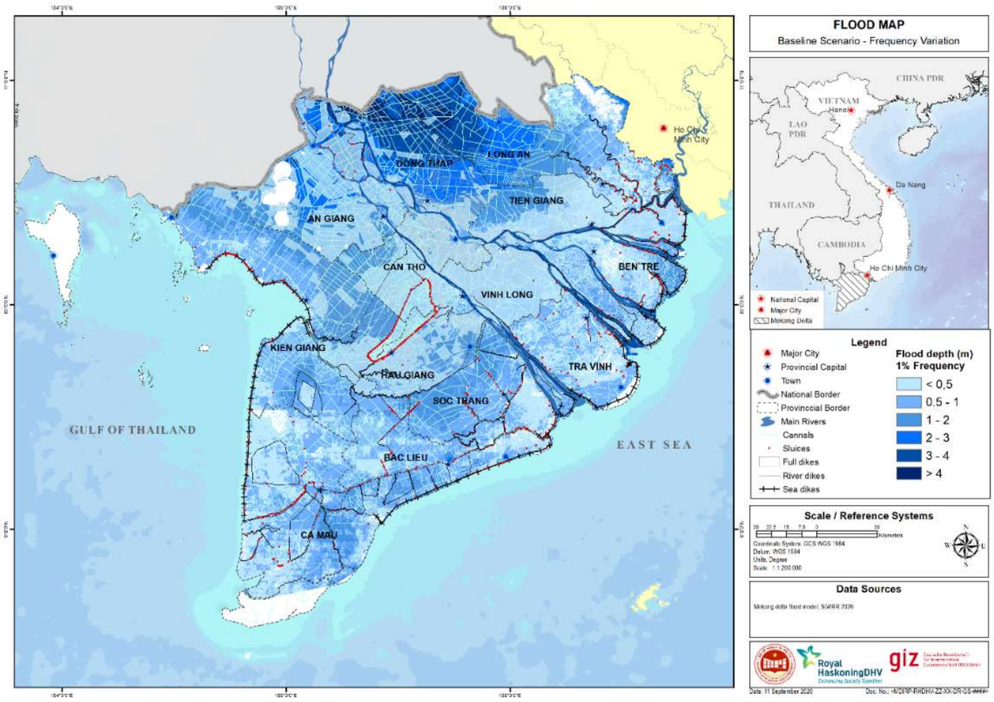


Figure 2-5 Maximum flood inundation depth and extent map for current infrastructure situation. Exceedance probability 1% (return period 1 in 100 years). Projection with climate change in 2030 (MDIRP, 2022)

3 Flood-based agriculture typologies

Several flood-based agriculture typologies already exists or have existed in the project area, for which upscaling in the upper Mekong Delta is considered. Other typologies like larger scale lotus cultivation are new. In changing climatic conditions other typologies may become realistic.

A distinction is made between flood-based agriculture and natural floodplain protection in low and high dike areas. Please refer to **Error! Reference source not found.** for the location of *current* areas with low and high dikes.

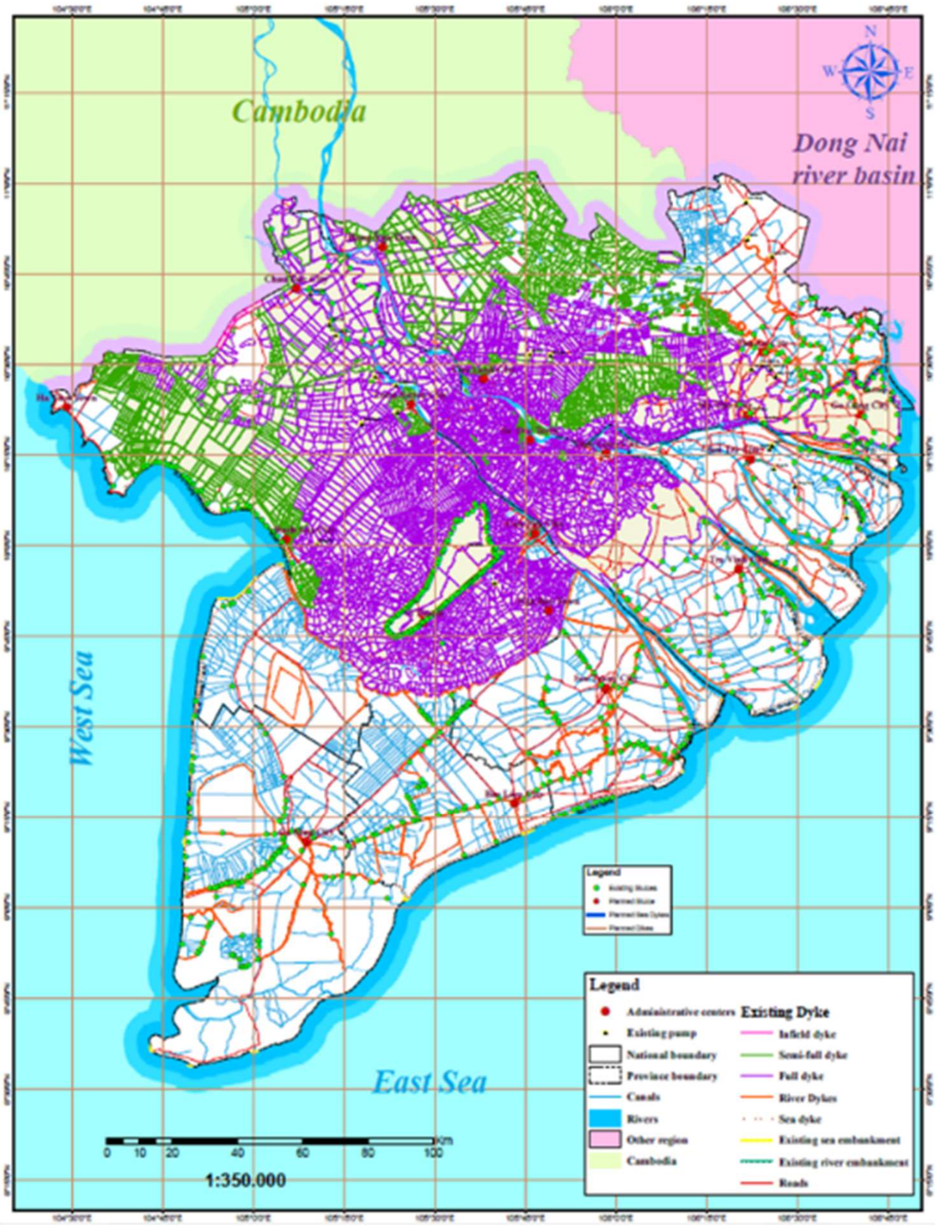
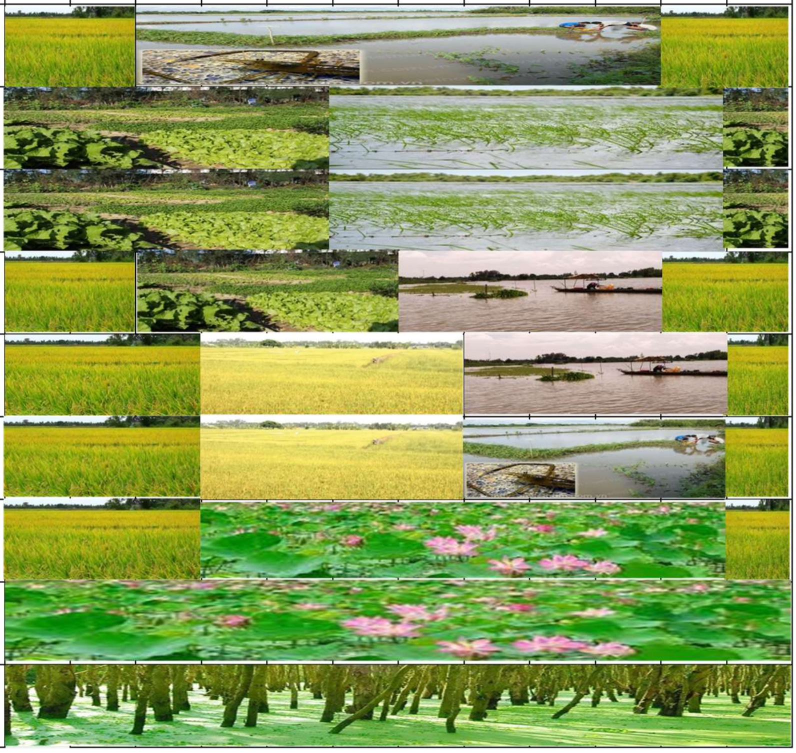


Figure 3-1 Existing system of high (purple colour) and low (green colour) dykes in the Upper Mekong Delta in Viet Nam (MDIRP, 2022)

Please note that whether a dike is ‘high’ or ‘low’ relates to the frequency of flood depths in a particular area. ‘High’ dikes in the north are higher in absolute sense than ‘high’ dikes in the middle of the delta.

Table 3-1 provides an overview of potential flood-based agriculture and forest rotation schemes.

Scheme	Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	(i) winter-spring rice, (ii) crayfish												
2	(i) upland crop, (ii) floating rice & crayfish												
3	(i) upland crop, (ii) floating rice & fish												
4	(i) winter-spring rice, (ii) upland crop, (iii) fish												
5	(i) winter-spring rice, (ii) summer-autumn rice, (iii) fish												
6	(i) winter-spring rice, (ii) summer-autumn rice, (iii) crayfish												
7	(i) winter-spring rice, (ii) lotus												
8	(i) lotus (& fish)												
9	(i) melaleuca timber plantations												



[1] Please note that the transition from one crop type to the next may vary depending on the location in the upper delta and the related arrival of the floods. The planting of winter-spring rice may start for example in November or December

Table 3-1 Typologies for flood-based agriculture (Andrew Wyatt, IUCN; Feasibility Study Mekong Delta Integrated Climate Resilience And Sustainable Livelihoods Project (MD-ICRSL) - WB9 project)

Each of the typologies listed above has specific requirements with respect to the water availability during the flood season. The requirements will be used for the identification of the land suitability.

Low dike areas

Flooding in low dikes areas is largely determined by the discharges in the Tien and Hau rivers during the flood season. Normally, the low dikes will be overtopped at some point during the flood season. Table 3-2 provides an overview of the lowest and highest flood peak level requirements for each of the identified typologies.

Please note that the specified requirements are used as *indicators.* The actual water requirements of the typologies are more complex and diverse. Farmers may for example also stock snakehead fish in the flood season when the flood levels and related oxygen levels are lower. The specified requirements do not yet include the re-fertilization due to siltation which is also an important factor which will be discussed in Chapter 5.

Table 3-2 Flood-based agriculture typologies with their flood inundation depth requirements. Low dike areas

	Typology	Minimum annual flood inundation depth (m)	Maximum annual flood inundation depth (m)
1	(i) winter-spring rice, (ii) crayfish	0.8 (2yr RP[1])	n/a

	Typology	Minimum annual flood inundation depth (m)	Maximum annual flood inundation depth (m)
2	(i) upland crop, (ii) floating rice & crayfish	0.8 (2yr RP)	n/a
3	(i) upland crop, (ii) floating rice & fish	2.0 (2yr RP)	n/a
4	(i) winter-spring rice, (ii) upland crop, (iii) fish	2.0 (2yr RP)	n/a
5	(i) winter-spring rice, (ii) summer-autumn rice, (iii) fish	2.0 (2yr RP)	n/a
6	(i) winter-spring rice, (ii) summer-autumn rice, (iii) crayfish	0.8 (2yr RP)	n/a
7	(i) winter-spring rice, (ii) lotus	0.5 (2yr RP)	2.0 (10yr RP)
8	(i) lotus (& fish)	0.5 (2yr RP)	2.0 (10yr RP)
9	(i) melaleuca timber plantations	0.5 (2yr RP)	2.0 (10yr RP)

[1] *RP = mean return period*

High dike areas

Flooding in high dike areas can be controlled up to the high dike levels that provide protection levels of once in 10-50 years. This means that the maximum flood level is no restricting factor anymore for low to moderately extreme floods. Only under very extreme floods the crops may be lost which is for now acceptable. Table 3-3 provides an overview of the lowest and highest flood peak level requirements for each of the identified typologies in high dikes areas.

Table 3-3 Flood-based agriculture typologies with their flood inundation depth requirements. High dike areas

	Typology	Minimum annual flood inundation depth (m)	Maximum annual flood inundation depth (m)
1	(i) winter-spring rice, (ii) crayfish	0.8 (2yr RP)	n/a
2	(i) upland crop, (ii) floating rice & crayfish	0.8 (2yr RP)	n/a
3	(i) upland crop, (ii) floating rice & fish	2.0 (2yr RP)	n/a
4	(i) winter-spring rice, (ii) upland crop, (iii) fish	2.0 (2yr RP)	n/a
5	(i) winter-spring rice, (ii) summer-autumn rice, (iii) fish	2.0 (2yr RP)	n/a
6	(i) winter-spring rice, (ii) summer-autumn rice, (iii) crayfish	0.8 (2yr RP)	n/a
7	(i) winter-spring rice, (ii) lotus	0.5 (2yr RP)	n/a
8	(i) lotus (& fish)	0.5 (2yr RP)	n/a
9	(i) melaleuca timber plantations	0.5 (2yr RP)	n/a

In high dikes areas, the typologies could be applied annually but also in rotations with rice every 2 or 3 years.

4 Suitability based on potential flooding extent

The approach to the selection of areas that are suitable for upscaling of flood-based agriculture and natural floodplain protection, is presented hereafter. The suitability mapping has been carried out for 4 groups of typologies that each have similar flooding requirements as listed in Table 3-2 and Table 3-3:

- *Group 1 – Crayfish*
  - T1: (i) winter-spring rice, (ii) crayfish
  - T2: (i) upland crop, (ii) floating rice & crayfish
  - T6: (i) winter-spring rice, (ii) summer-autumn rice, (iii) crayfish
- *Group 2 – Fish stocking*
  - T3: (i) upland crop, (ii) floating rice & fish
  - T4: (i) winter-spring rice, (ii) upland crop, (iii) fish
  - T5: (i) winter-spring rice, (ii) summer-autumn rice, (iii) fish
- *Group 3 – Lotus*
  - T7: (i) winter-spring rice, (ii) lotus
  - T8: (i) lotus (& fish)
- *Group 4 - Forest*
  - T9: (i) melaleuca timber plantations

4.1 Group 1 – typologies 1, 2 and 6 - crayfish

The following criteria have been applied to stepwise exclude areas that are not suitable for upscaling of flood-based agriculture or natural floodplain protection:

1. *Focus area.* Include only the provinces in the focus area: Can Tho, Kien Giang, Hau Giang, An Giang, Tien Giang, Dong Thap and Long An (see Figure 4-1).

2. *Suitable land use planning in 2050.* Include only the areas suitable for upscaling of flood-based agriculture and natural floodplain protection that are included in the MDIRP agricultural land use planning for 2050. These land use types are shown in Figure 4-2: rice (yellow), rice/aquaculture (light green) and forest (green). The relevant land use types in the focus area are presented in Figure 4-3.

3. *Agricultural and nature protection land use only.* All areas with a population density over 500 per km^2 and industrial sites are considered unsuitable for upscaling of flood-based agriculture or natural floodplain protection (see Figure 4-4). The land suitability based on the chosen geographical and land use planning criteria is shown in Figure 4-5.

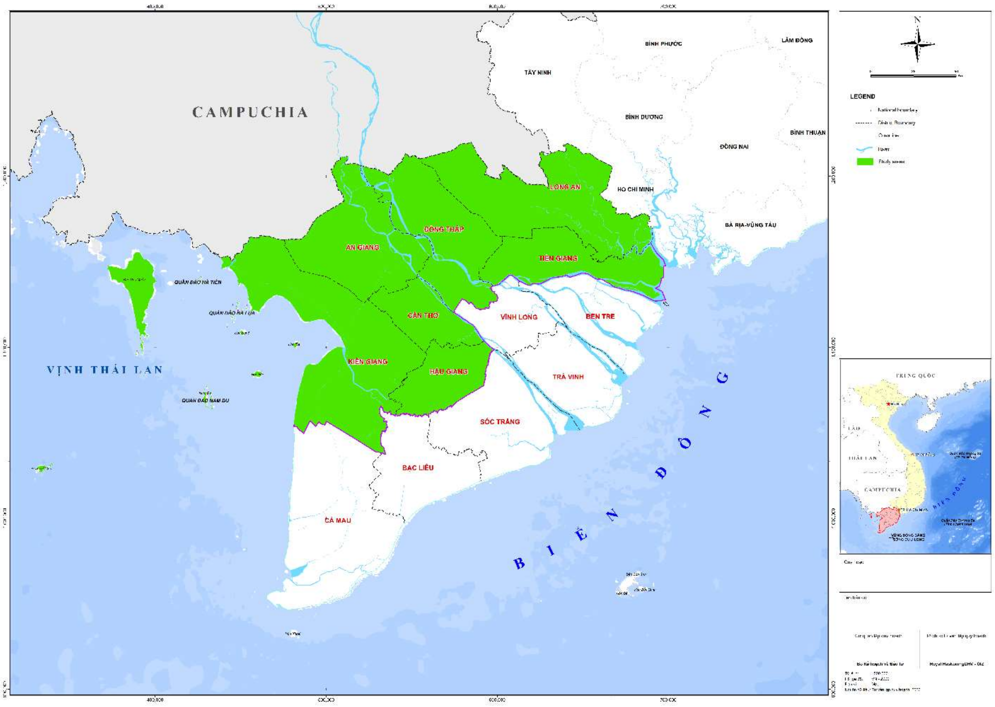


Figure 4-1 Provinces in focus area

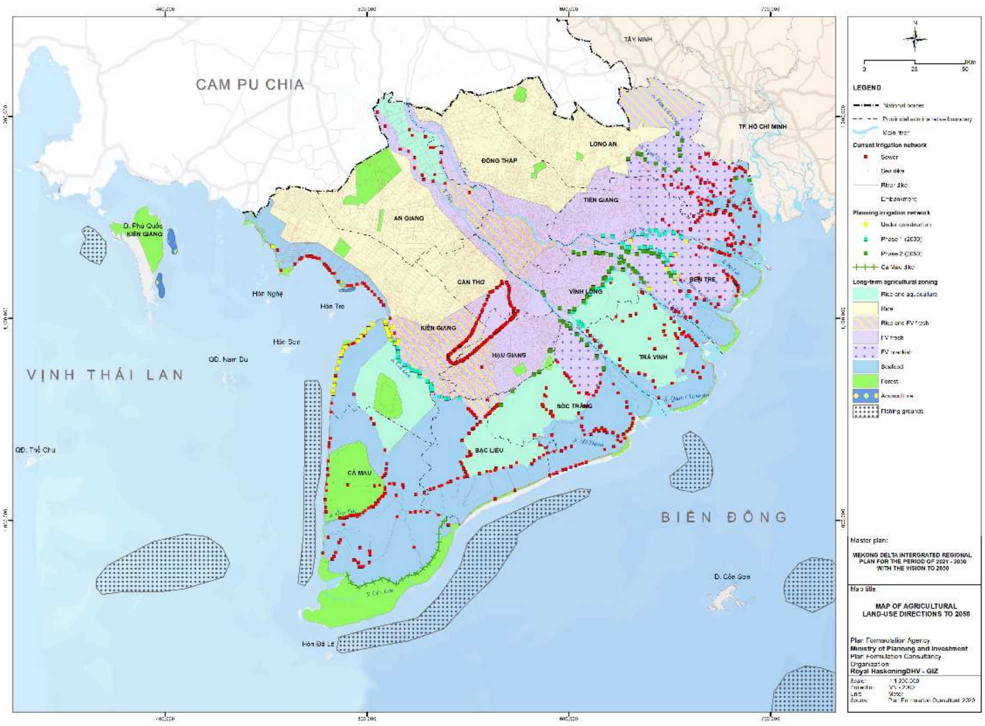


Figure 4-2 Agricultural land-use directions to 2050 (MDIRP, 2022)

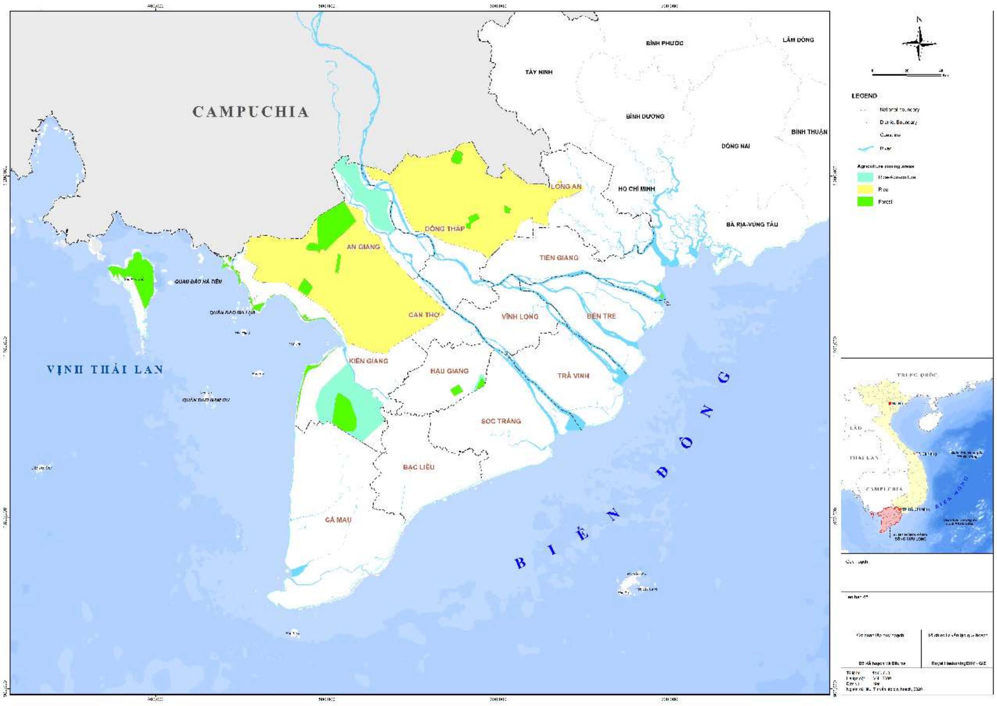


Figure 4-3 Suitable agricultural typologies in MDIRP land use planning for 2050

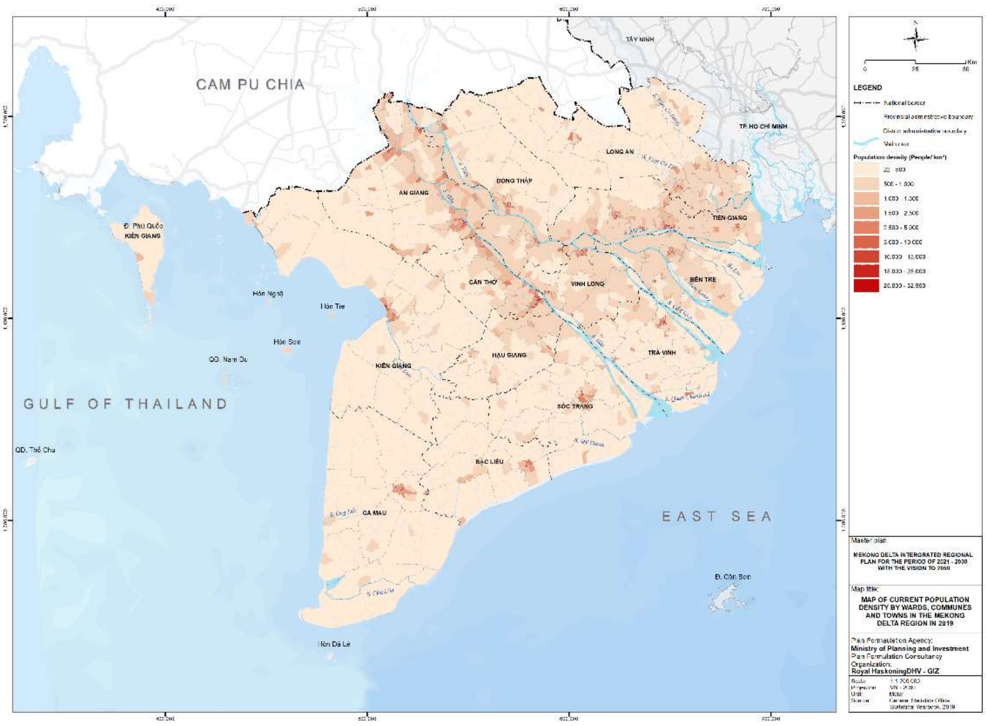


Figure 4-4 Population density 2019 (MDIRP, 2022)

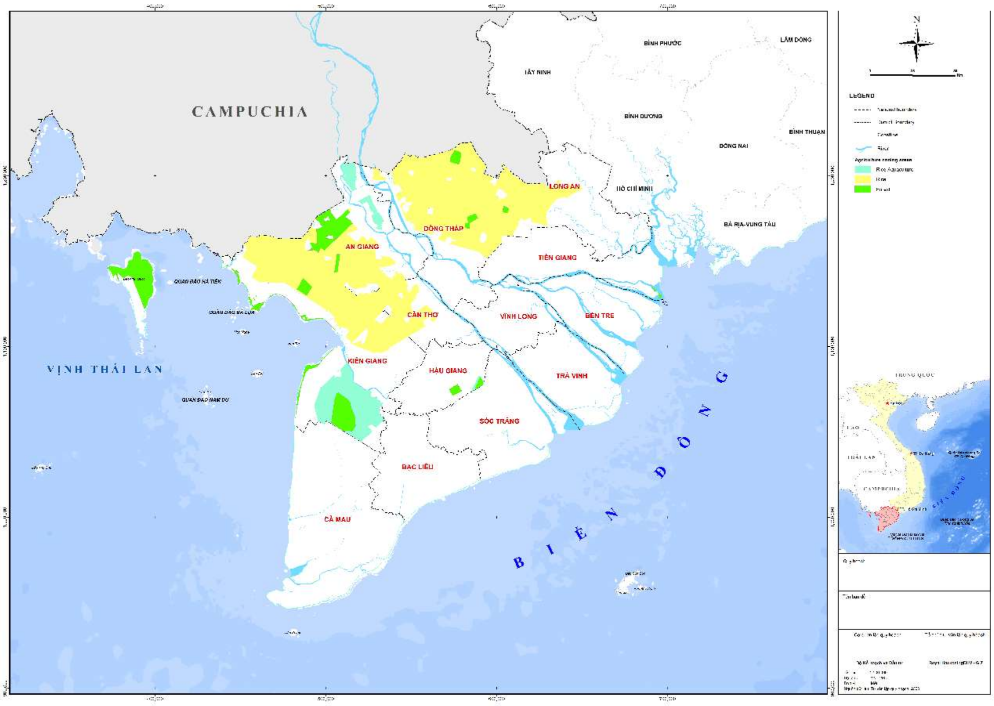


Figure 4-5 Suitable agricultural land use planning for 2050 excluding areas with a population density over 500 per km² and industrial areas

4. *Adequate annual maximum flood inundation level.* The minimum flood inundation depth in both low and high dike areas is 0.8m assuming a flooding frequency of 50% which is similar to a return period of 2 years. There are no upper limits to the annual flood inundation depth. See Table 3-2 and Table 3-3 for an overview of the requirements.

The maximum inundation depths for a flood frequency of 50%, are provided Figure 4-6. These have been simulated with a hydraulic model for the case in which *no dikes* have been assumed. The case without dikes is taken as the reference for determining the suitability with respect to flooding depth. This is the situation that could be largely realized by opening the inlet structures to the dike rings or by removing all or part of the dikes.

The resulting suitability map for typologies 1, 2 and 6 is shown in Figure 4-7. These typologies combine crayfish or aquaculture in the flood season with rice, floating rice or upland crops in the remainder of the year. The areas that are suitable for upscaling these types of flood-based agriculture stretch over large parts of An Giang and Dong Thap provinces. Also some areas in the northeast of Kien Giang, the northwest of Can Tho, and the west of Long An are suitable.

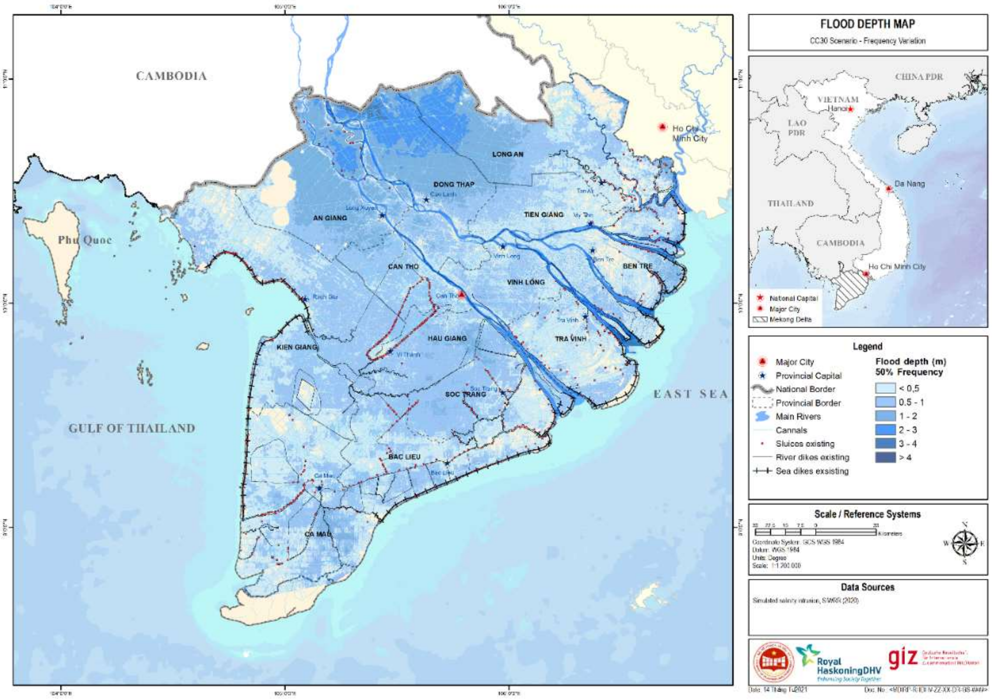


Figure 4-6 Water availability (case with no dikes). Maximum flood inundation depth and extent map for current infrastructure situation. Exceedance probability 50% (return period 1 in 2 years). Projection with climate change in 2030 (MDIRP, 2022)

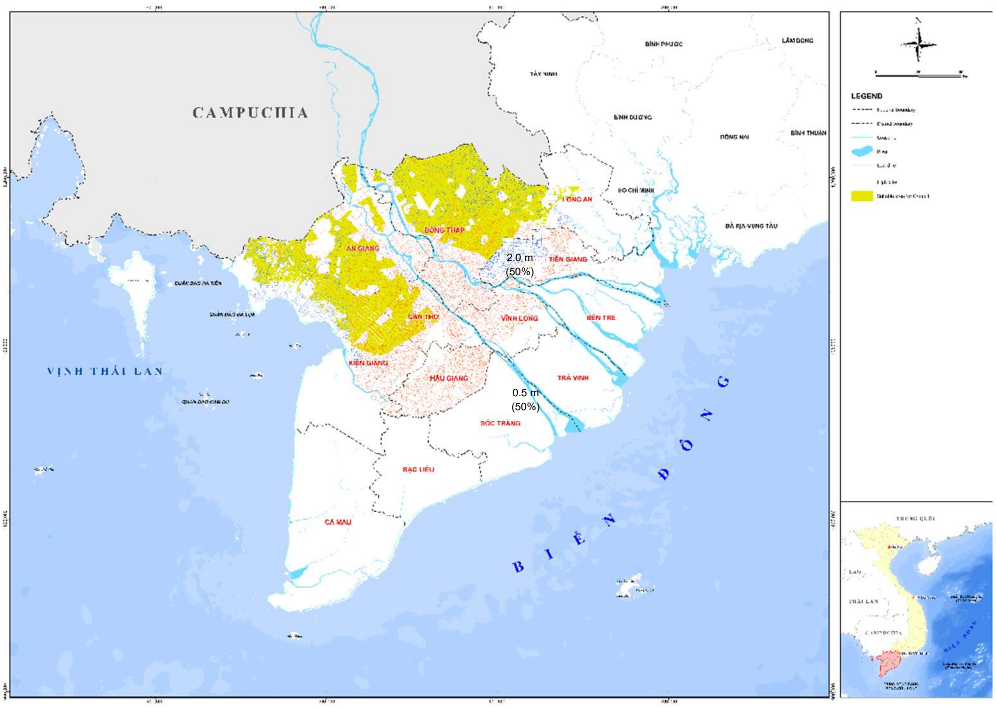


Figure 4-7 Suitability for typologies 1, 2 and 6 (crayfish or aquaculture)

4.2 Group 2 – typologies 3, 4 and 5 – fish stocking

For the typologies in group 2, the steps 1 to 3 discussed above in 0 are the same. The flood inundation depth requirements are however different.

4. *Adequate annual maximum flood inundation level.* The minimum flood inundation depth in both low and high dike areas is 2.0m assuming a flooding frequency of 50% which is similar to a return period of 2 years (see Figure 4-6). There are no upper limits to the annual flood inundation depth. See Table 3-2 and Table 3-3 for an overview of the requirements.

The resulting suitability map for typologies 3, 4 and 5 is shown in Figure 4-8. These typologies combine natural fishing in the flood season with rice, floating rice or upland crops in the remainder of the year. The areas that are suitable for upscaling these types of flood-based agriculture are mainly located in Dong Thap province. Also areas in the northeast part of An Giang province and west of Long An province are suitable.

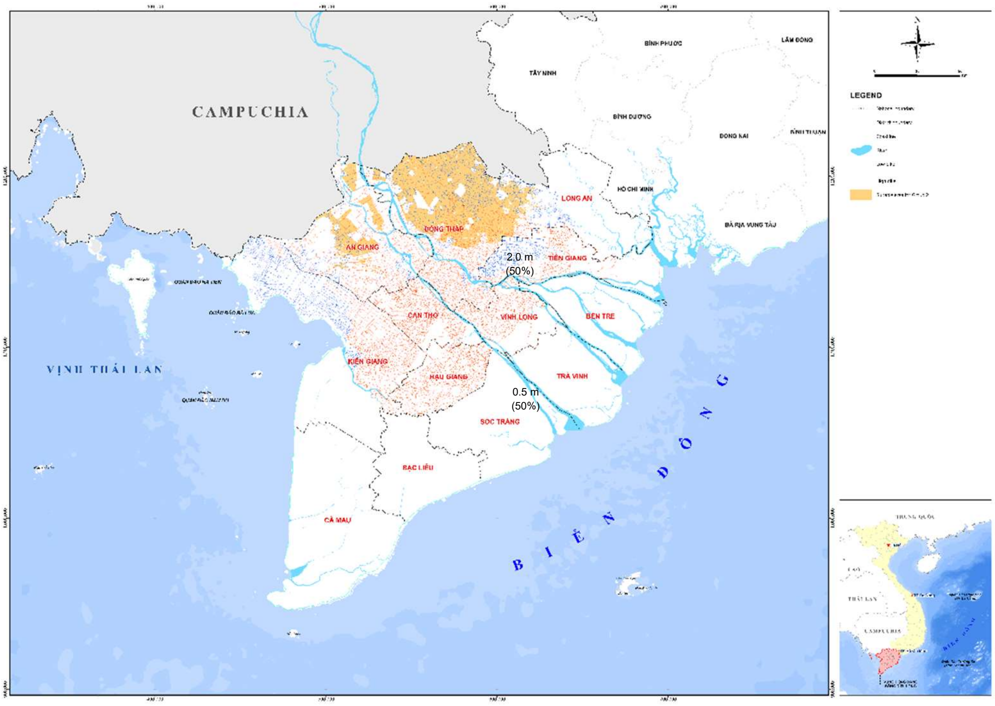


Figure 4-8 Suitability for typologies 3, 4 and 5 (natural fishing)

4.3 Group 3 – typologies 7 and 8 - lotus

For the typologies in group 3, the steps 1 to 3 discussed above in 0 are the same. The flood inundation depth requirements are again different.

4. *Adequate annual maximum flood inundation level.* The minimum flood inundation depth in both low and high dikes areas is 0.5m assuming a flooding frequency of 50% (see Figure 4-6). The maximum flood inundation depth in low dike areas is 2.0m assuming a flooding frequency of 10% which is similar to a return period of 10 years (see Figure 4-9). For the maximum flood depth, a lower exceedance frequency is applied because the lotus crop may be lost in case the flood depth becomes too large. Such event should happen only infrequently (less than once every 10 years).

There are no upper limits to the annual flood inundation depth in high dike areas. See Table 3-2 and Table 3-3 for an overview of the requirements.

The resulting suitability map for typologies 7 and 8 is shown in Figure 4-10. These typologies combine lotus planting with rice in the dry season or natural fishing. The areas that are suitable for upscaling these types of flood-based agriculture are mainly located in An Giang province. Other suitable areas are located in the east of Dong Thap province, the west of Long An province, the northeast of Kien Giang province and the northwest of Can Tho province are suitable.

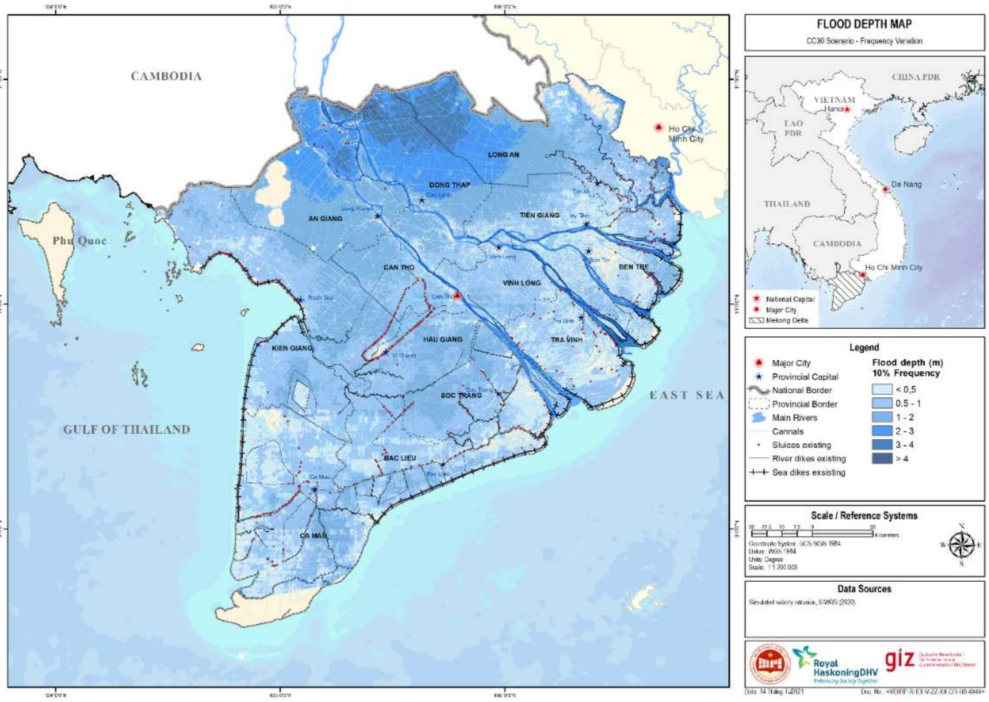


Figure 4-9 Water availability (case with no dikes). Maximum flood inundation depth and extent map for current infrastructure situation. Exceedance probability 10% (return period 1 in 10 years). Projection with climate change in 2030 (MDIRP, 2022)

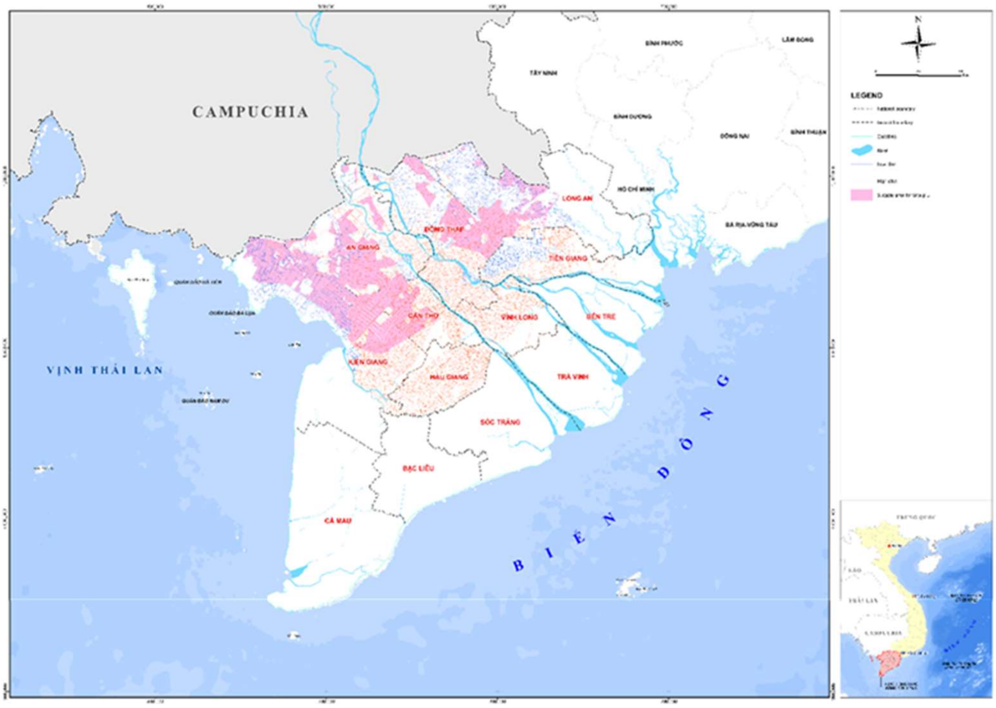


Figure 4-10 Suitability for typologies 7 and 8 (lotus)

4.4 Group 4 – typology 9 - melaleuca

For the typology 9 (group 4), the steps 1 to 3 discussed above in 0 are the same. Subsequently, the following steps have been taken:

4. *Planning.* Only area has been included that is planned as forest in the MDIRP land use map for 2050 (see Figure 4-11).
5. *Poor soil quality.* In addition to the 'planned forest area', area has been included with acid-sulphate soils (see Figure 4-11)
6. *Adequate annual maximum flood inundation level.* The minimum flood inundation depth in both low and high dikes areas is 0.5m assuming a flooding frequency of 50% (see Figure 4-6). The maximum flood inundation depth in low dike areas is 2.0m assuming a flooding frequency of 10% (see Figure 4-9). For the maximum flood depth, a lower exceedance frequency is applied because the melaleuca trees may be lost in case the flood depth becomes too large. Such event should happen only infrequently (less than once every 10 years). There are no upper limits to the annual flood inundation depth in high dike areas. See Table 3-2 and Table 3-3 for an overview of the requirements.

The resulting suitability map for typology 9 is shown in Figure 4-12. This typology is perennial melaleuca forest. The areas that are suitable for upscaling this type of natural floodplain protection are located in the northeast of Kien Giang, the southwest of An Giang province, the northwest of Can Tho province, the east of Dong Thap province and the west of Long An province.

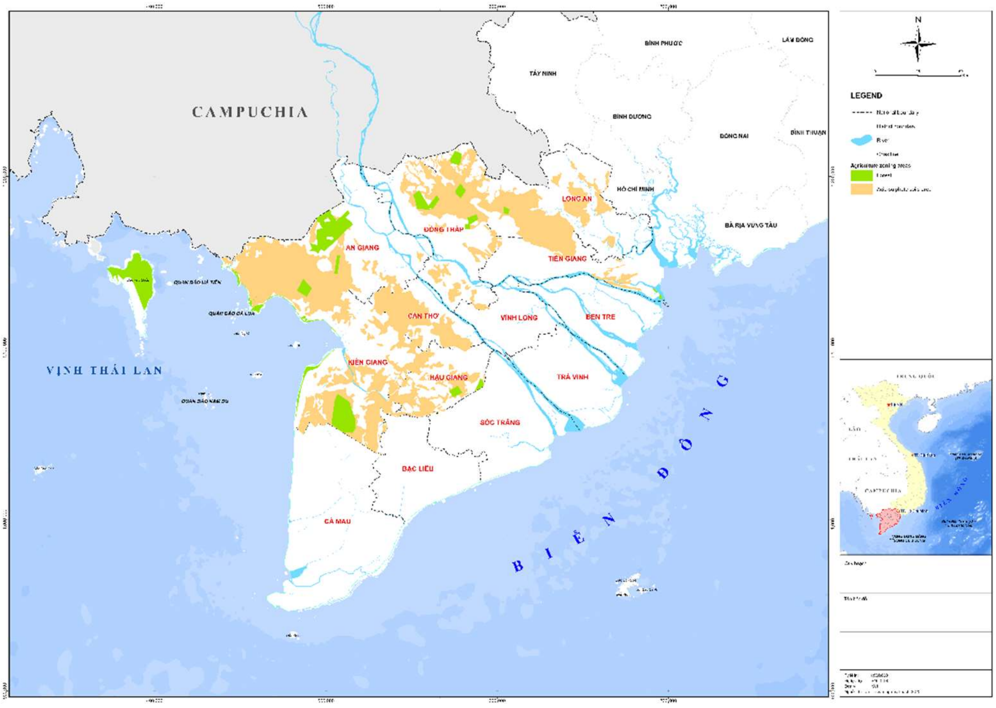


Figure 4-11 Forest in MDIRP land use planning 2050 and areas with acid-sulphate soils

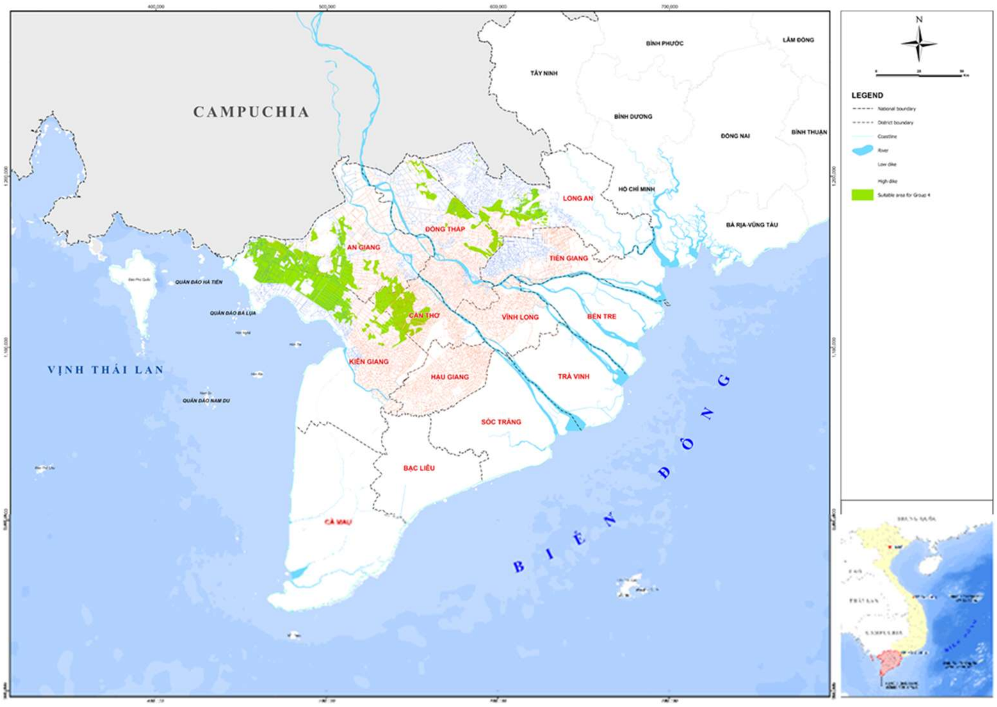


Figure 4-12 Suitability for typology 9 (melaleuca)

5 Re-fertilisation and growing with sea level rise

In the previous paragraphs suitability mapping was done based on specific (natural) circumstances such as water depth and land use. The circumstances determine which type of flood-based agriculture could be introduced. There are, however, also aspects that are necessary for long term sustainability. These aspects are independent of the type of flood-based agriculture. In order to be able to have flood-based agriculture for many decades the most important aspects to take into account are re-fertilisation and growing with sea level rise. Both aspects are connected to the sediment that is transported via the rivers into the floodplains of the delta. Nutrients that re-fertilize the soils are attached to the fine sediment particles while the fine sediment particles themselves increases land levels as a result of sedimentation.

- *Re-fertilization*. Sufficient fine sediment should reach the fields in the flood season to provide nutrients to crops. Otherwise, fertilizers will need to be used to boost the crop production. Resulting in higher costs and pollution.

- *Growing with sea level rise.* Sea level rise and land subsidence will gradually turn land into wetlands and then water in case insufficient sedimentation takes place. Natural floodplains have almost disappeared in the upper delta as a result of dike building.

Sedimentation and erosion are natural processes in every delta, and also in the Mekong Delta in Viet Nam. Due to catchment development, dam and dike building, river training, sand mining and other anthropogenic influences, the sedimentation and erosion processes have changed dramatically over the past decades. More changes are foreseen in the future. These changes have strong impacts on the land suitability for upscaling flood-based agriculture and natural floodplain protection. In short, the lack of sedimentation in the upper delta can strongly hamper the so needed re-fertilization and the growing with sea level rise.

Hereafter, a ‘reasoning model’ has been developed to assess the sediment availability for accommodating the abovementioned aspects in relation to the land suitability for upscaling of flood-based agriculture and natural floodplain protection. Focus at first is at the re-fertilization aspect. The reasoning model should give insight in how much land can be turned into flood-based agriculture land, based on the assumption that re-fertilization is needed for long term sustainable flood-based agriculture.

Sediment availability

The construction of hydropower dams and reservoirs upstream in the Mekong River Basin has a strong impact on especially the sediment availability in the river. The current active reservoir storage in the Mekong Basin is 14% of the mean annual flow. The active reservoir storage is expected to increase to 22% in the coming decade. Qualitative assessments of the impact of dam building can be found in the MRC Council Study (2017)[3] and in the DHI-MONRE impact study (2015)[4].

Dam building will reduce sediment fluxes in the river because of trapping in reservoirs. For the Mekong Delta this will mean a sharp reduction in suspended sediment that is transported with the (flood) flows. MRC studies predict a reduction in suspended sediment load into Vietnam with an astonishing 97% by 2040 compared to situation prior to the major dam construction in the 1990’s. This very large reduction of suspended sediment loads is seriously impacting river and coastal ecosystems in the Mekong Delta and the coastal waters. It will also reduce soil fertilisation through the annual inundation of fields. The reduction in the transport of coarser sediment (sand) will be affected by reservoir building upstream on a much longer term (hundreds of years) and will only be noticed to a limited extent in the delta.

[3] *Council Study, 2017, MRC; Key Messages from the Study on Sustainable Management and Development of the Mekong River Basin, including Impact of Mainstream Hydropower Projects, Version 0.8, 23 November 2017.*

[4] *Study on the Impacts of Mainstream Hydropower on the Mekong River - Final Report, DHI-MONRE, 2015.*

Figure 5-1 shows that the annual total suspended sediment (TSS) at Kratie is predicted to have been reduced from about 150 Mt/year in the baseline 2007 to about 4 Mt/year in 2040. This is a reduction of 97%. A recent publication[5] showed that the influx of suspended sediment into Viet Nam via the Tien and Hau rivers reduced from 167 Mt/year in the pre-dam period prior to the 1990's to 43 Mt/year in the period 2012-15, a reduction of around 74%. This data shows that by 2040 and beyond – at the current rate of dam building in the river basin – the influx of suspended sediment to Viet Nam is likely to have reduced over 97% to about 5 Mt/year.

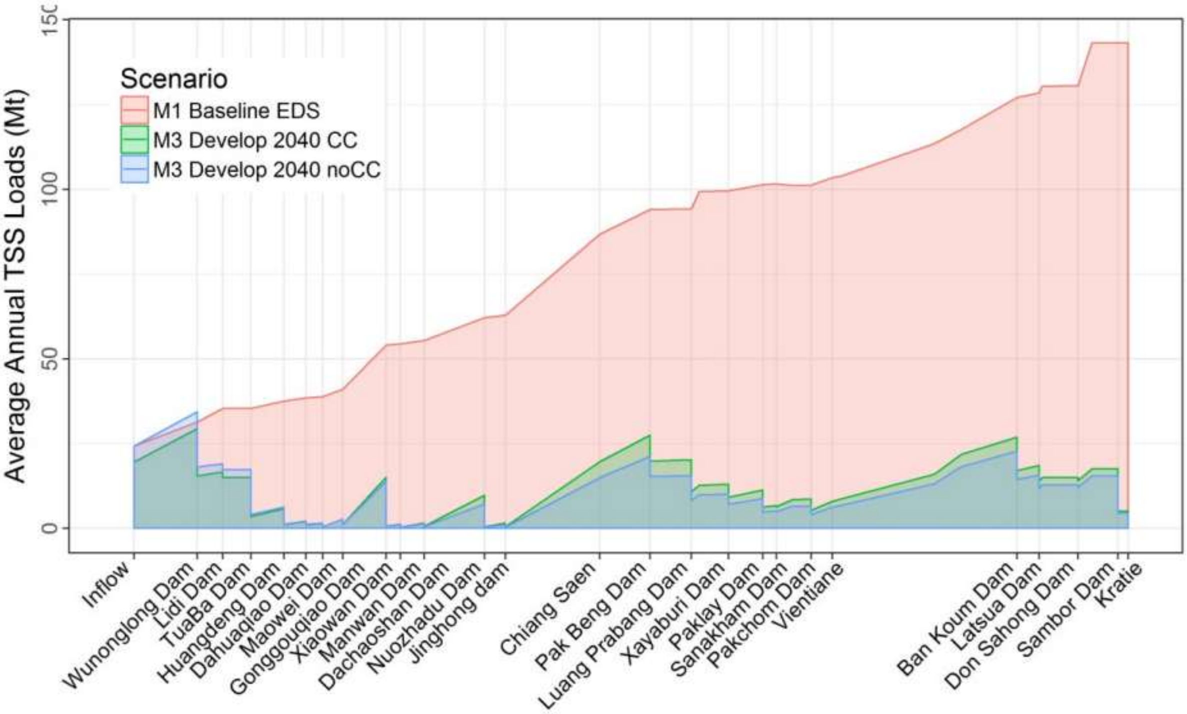


Figure 5-1 Comparison of average annual TSS loads on the Mekong (and Lancang) River for the Development 2040 scenario with and without climate change. Baseline scenario results are included for reference[6]

Suspended sediment is transported with the flows in the river. Higher in the water column concentrations are less than at lower depths in the river. Figure 5-2 shows the flow distribution in upper Mekong Delta. The diagram indicates that the total annual inflow into Vietnam via the Hau and Tien rivers and directly across the border is between 390 and 425 Bm^3. Between 79 and 91 Bm^3 of this flow volumes passes the lands adjacent to the river which is about 26%. The remainder is passed downstream by both main river channels, the Hau and the Tien river.

[5] Doan Van Binh, Sameh Kantousha and Tetsuya Sumia, 2020. Changes to long-term discharge and sediment loads in the Vietnamese Mekong Delta caused by upstream dams
[6] MRC, 2017. Thematic Report on the Positive and Negative Impacts of Hydropower Development on the Social, Environmental, and Economic Conditions of the Lower Mekong River Basin. The Study on the Sustainable Management and Development of the Mekong River Basin, including Impacts of Mainstream Hydropower Project. The Council Study

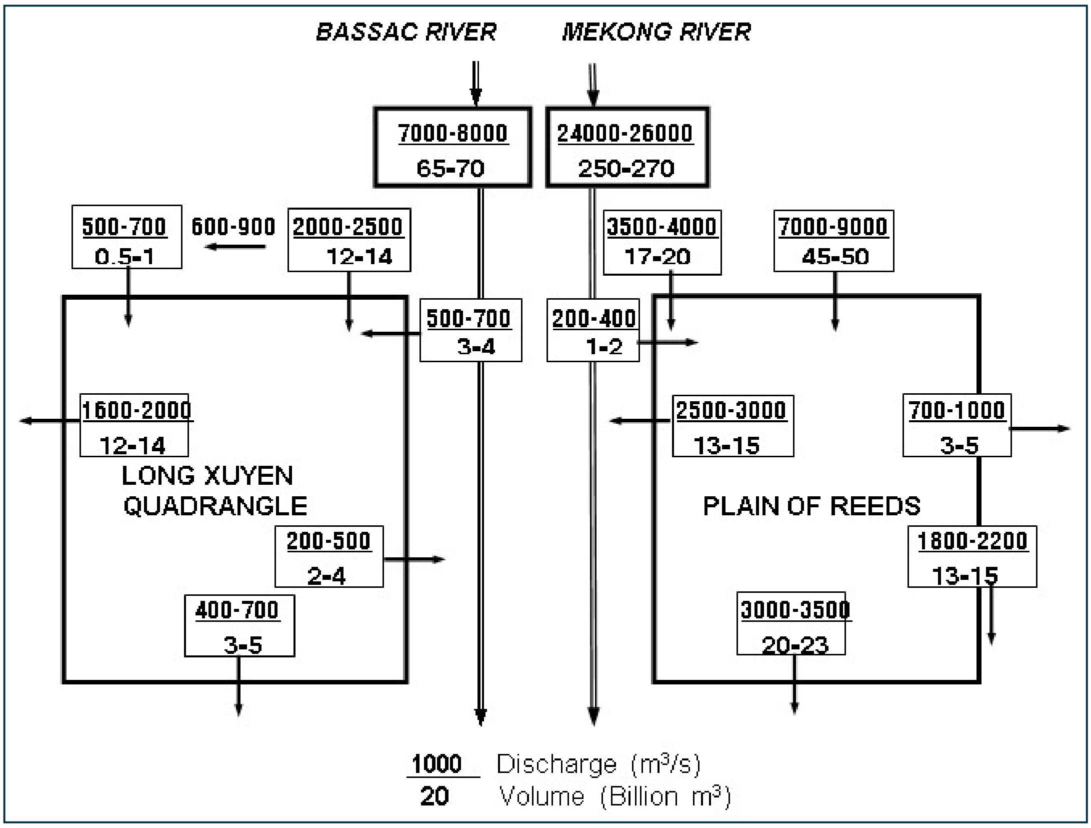


Figure 5-2 Average flood discharge and total volume Mekong Delta[7]

In case we assume that roughly 25% of the suspended sediment is transported in the upper layers of the water column of the river, the total amount of sediment that will be diverted to the floodplains will be 25% of 26% (equals to 6.5%) of 5 Mt/year. This equals 0.325 Mt/year. Assuming a specific weight of suspended matter of 1.1 kg/l, this translates in about 0.295 Mm^3/year.

The distribution of water and sediment over Long Xuyen Triangle and the Plain of Reeds is uncertain. Therefore, also an alternative publication is used to derive this distribution (see Figure 5-3). This publication estimates that about 11% (instead of 6.5%) of the total annual flow at Kratie is passing the flood plains in the Upper Mekong Delta in Viet Nam. This translates into a mean annual sediment availability of 0.500 Mm^3/year.

Please note that the flow over the border with Cambodia via the floodplains is by far the largest. This also means that the sediment influx over the border is by far the largest in this reasoning. Since the date of both publications that are referred to above, Viet Nam has been building a border dike. This is expected to have substantially reduced the sediment influx into Long Xuyen Triangle and the Plain of Reeds. So the conclusions hereafter are probably a substantial overestimation of the sediment availability.

[7] *Source: SIWRP.*

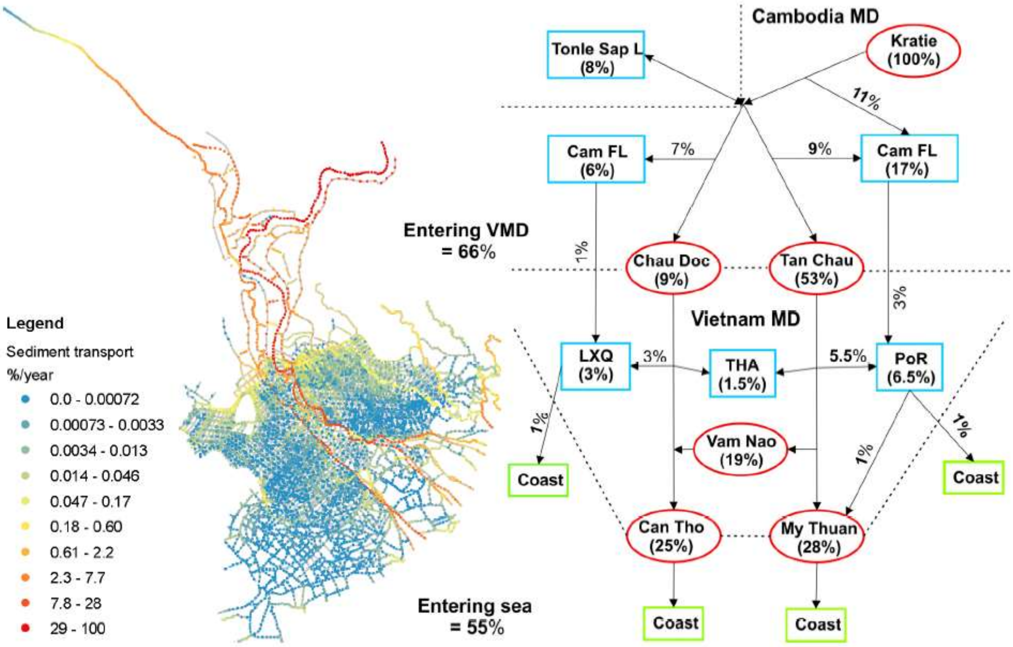


Figure 5-3 Water distribution in Mekong Delta[8]

Re-fertilisation

To adequately re-fertilise the soils in the Upper Mekong Delta, it is roughly estimated that an average annual layer of suspended sediment is required of around 1 mm/yr. This means that with the sediment available in 2040, a maximum total area of 30-50,000 ha could be effectively re-fertilised with the suspended sediment available in 2040. This corresponds to only 2-4% of the area of Long Xuyen Triangle and the Plain of Reeds.

The river flow carries substantially more suspended sediment and nutrients than could be diverted to the fields using current water management system and practices. In case the diversion of fine sediments and nutrient could be increased, a larger area could be re-fertilized. The latter seems however difficult to realize in practice.

Keeping up with relative sea level rise

The sea level rise is assumed to be around 1 cm per year. Given the nearly flat terrain in the delta, this is assumed to be valid too for the rise of the river levels in the upper MDR. The average land subsidence in the upper delta is also about 1 cm per year although substantial differences have been recorded. This means that the relative rise of the river levels is about 2 cm/yr. This has to be compensated by sedimentation in order to maintain a natural floodplain. In reality, the order of magnitude of the annual sediment deposits in the 're-fertilization' area mentioned above is only in the order of 0.1 cm/yr.

In case it is theoretically assumed that all available sediment could be 'used' for restoring a natural floodplain, the total area for which this could be realised would only be around 1,500-2,500 ha. This equals 0.1-0.2% of the Long Xuyen Triangle and the Plain of Reeds. Concentrating all sedimentation in this limited area will however be practically impossible and also not desirable.

Given the fact that the relative sea level rise is outpacing the sedimentation process, the mean sea levels will gradually rise above the land levels. In order to sustain land-based activities towards the end of this

[8] N. V. Manh, N. V. Dung, N. N. Hung, B. Merz, and H. Apel, 2014. Large-scale suspended sediment transport and sediment deposition in the Mekong Delta

century, the larger part of the delta will need to be gradually transformed into polders with dikes and pumping stations. Uncontrolled parts of the delta will gradually transform into wetlands and subsequently open water.

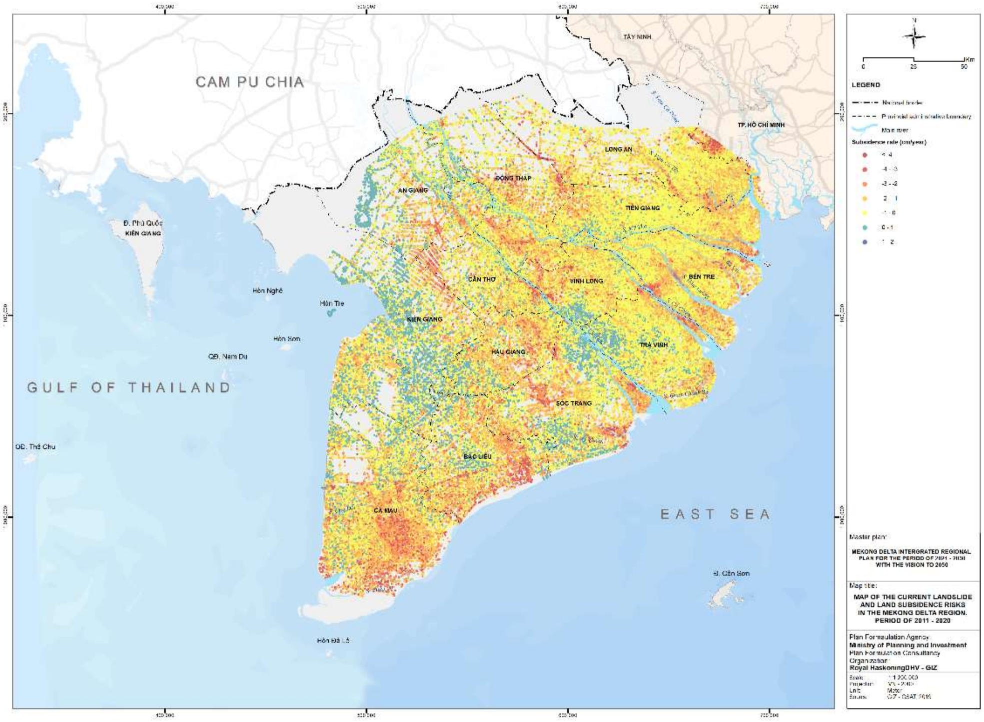


Figure 5-4 Land subsidence rate in cm/yr in 2020 (ref. MDIRP)

6 Potential interventions

Limited scope of upscaling

The analysis in the previous sections suggests that the scope for upscaling flood-based agriculture and natural floodplain protection is limited in the upper delta in Vietnam. The availability of flood water, needed to restore more natural inundation patterns in a larger parts of the upper delta, is sufficient as is illustrated in the summary diagram in Figure 6-1. The suspended sediment availability, however, which is crucial for actual re-fertilization, is limited. The suspended sediment availability will definitely be inadequate for ensuring a deposition rate in the floodplains that keeps up with relative sea level rise.

The conclusion of the study is that the scope for upscaling flood-based agricultural typologies on a large scale for the longer term is very limited. Small scale and locally focussed upscaling measures are possible. However, on the long run this path is not sustainable as most of the area will suffer from a serious lack of fine sediments and thus a degrading soil quality. Due to a lack of sediment deposits, sea level rise and land subsidence, the surface levels will gradually fall below the river levels during all or the larger part of the year.

Restoring flood dynamics for flood-based agriculture and nature conservation

The focus of interventions could therefore be shifted to aiming to maintain and expand the combination of flood-based agriculture and nature conservation. A primary focus could for example be on restoring the flood dynamics in the area between the Tien river and Tram Chin national park. Similarly, focus areas could be found elsewhere in the Plain of Reeds and the parts of An Giang around Tra Su Cajuput forest. This type of development will also provide opportunities for eco-tourism.

Need for flood risk sensitive spatial planning

The abovementioned developments need to part of a flood risk sensitive spatial planning for the Mekong Delta in Viet Nam. Development of the latter has been proposed in the Mekong Delta Integrated Regional Planning (MDIRP) but has by no means been formalised at this stage. Flood risk sensitive spatial planning takes into account that providing a high level of protection against flooding (e.g. less than 1% risk of inundation) for the full delta will be difficult to finance at shorter time scales. Therefore, areas with a higher potential damage and vulnerability (domestic areas, industrial sites, critical infrastructure, orchards, fish ponds etc.) should be better protected than other areas via a combination of dike systems and formalised operational flood management. Land use planning and associated flood protection should be systematically synchronised. Within such context, the upscaling of flood-based agriculture and nature conservation could be effectively realized.

Collection of field data on sedimentation potential

The limited availability of suspended sediments and nutrient in the flood waters that are diverted into the agricultural and natural areas in the upper delta is identified as the main limiting factor for upscaling flood-based agriculture and natural floodplain protection. There is however very little field research undertaken in the upper Mekong Delta in Viet Nam to verify the actual deposition rates. It is therefore strongly advised to set up a comprehensive field campaign - and potentially a supporting modelling study - to collect field evidence on the sedimentation rates prior to large scale interventions to support the upscaling. This should preferably start in the flood season 2023 given the importance of the topic.

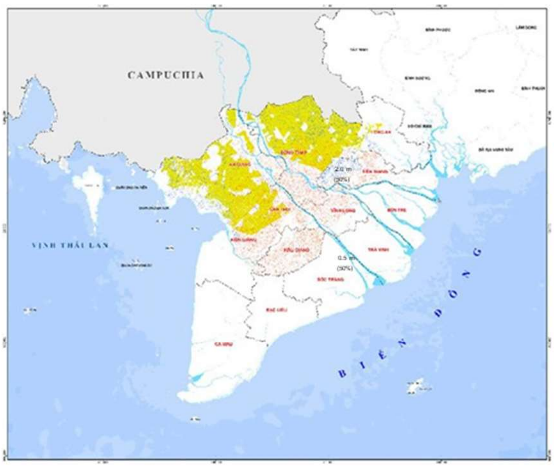
Increase the suspended sediment and nutrient transport in the river and diversion canals

The suspended sediment transport in the Mekong River could be increased by introducing a systematic sluicing of reservoirs at especially the onset of the flood season when floods generally carry most sediment. This requires international cooperation, and negotiations about trade-offs. Sluicing will impact the energy production and storage for water supply. In order to judge whether increasing the suspended sediment loads in the river will actually contribute to the upscaling ambitions, conducting the abovementioned field campaign is essential.

Group 1

Typologies 1, 2 and 6 (crayfish and aquaculture)

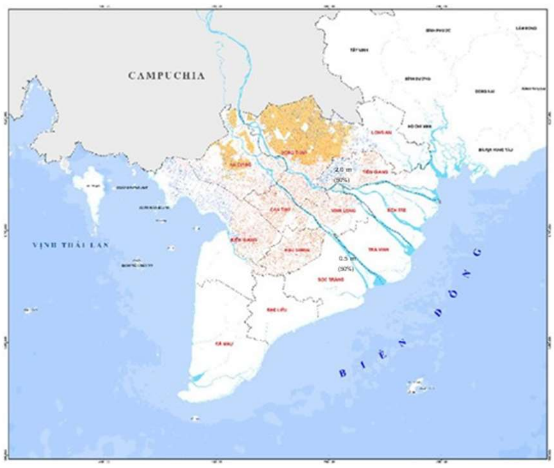
Group 1	Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1	Winter Spring rice + Crayfish												
2	Floating rice + Aquaculture + Upland Crop												
6	Winter Spring rice + Summer Autumn rice + Crayfish												



Group 2

Typologies 3, 4 and 5 (natural fishing)

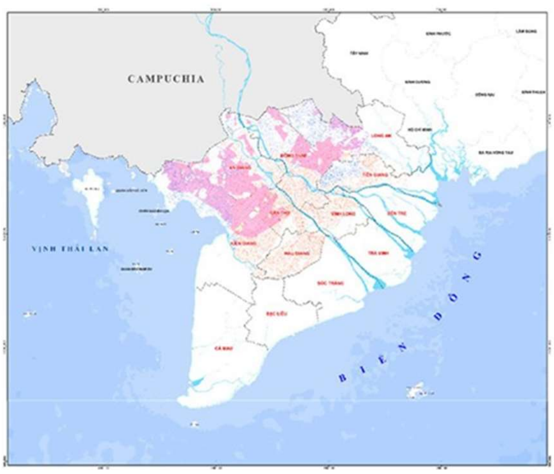
Group 2	Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
3	Floating rice + Natural fishing + Upland Crop												
4	Winter Spring rice + Upland crop + Natural Fishing												
5	Winter Spring rice + Summer Autumn rice + Natural fishing												



Group 3

Typologies 7 and 8 (lotus)

Group 3	Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
7	Winter Spring rice + Lotus												
8	Lotus + Fish												



Group 4

Typology 9 (melaleuca)

Group 4	Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
9	Melaleuca + timber plantations												

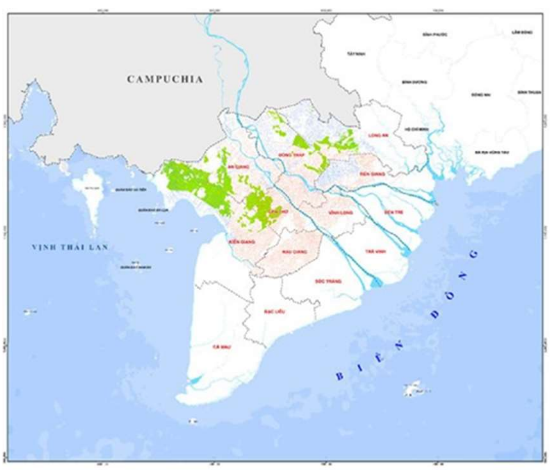


Figure 6-1 Overview of suitability maps for each of the typology groups