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# A flora of agricultural and horticultural crops

A quick scan of selected crops in the Mekong Delta



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# Preface

On 15 March 2016, the Vietnamese government and the United Nations Development Programme (UNDP) organized a meeting with donors, international organizations and other partners to discuss joint efforts for drought response and recovery. Another meeting was presided by the Ministry of Agriculture and Rural Development (MARD) Minister Cao Duc Phat and the UN Resident Coordinator on 30 March 2016 to report on the recent rapid assessments of current natural hazards and call for immediate, medium- and long-term support from the international community. MARD recognizes that this crisis and its subsequent effects (e.g. inundation after the drought) will recur in the future, and that there is a need to prepare and plan for necessary response measures. Herewith started the process, that resulted in the commissioning and financing of this quick scan by the Rijksdienst voor Ondernemend Nederland. The quick scan is the key output of the project 'Mapping the potential (quick scan) for salt and drought tolerant crops and cropping systems in the Mekong Delta' with the purpose to develop a sustainable climate smart agriculture in the Mekong Delta to secure food and income of farmers by providing them knowledge and information to respond to salt and drought stress in agriculture.

The quick scan will map, using a literature review and interviews with local and international experts, current and promising crops. Bringing in local expertise is done by connecting to the University of Can Tho, East West and the local farmers' organisation.

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# Summary

Vietnam is one of the most vulnerable countries to the impacts of climate change. Its extensive lowland coastal areas which support most of the country's agriculture and aquaculture production, is particularly susceptible to flooding and saline intrusion. The government realizes that there is an urgent need to prepare and plan for necessary response measures. Therefore, a quick scan focussing on the Mekong River Delta, using international and local expertise with the aim to identify promising crop and cropping system level strategies to address salt and drought stress. Moreover, acidity and humidity stress will be addressed to certain extent also.

Based on a literature review and interviews with local and international experts, the quick scan maps current and promising crops, in total 29 species, and cropping system level strategies to respond to stress circumstances in agriculture. For each crops a short 1 page information sheet is created with Latin name, vernacular names, drought sensitivity, salinity sensitivity, thresholds and recognizing stress, current tillage, management practices and recommendations.

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# 1 Introduction

The economy in the Mekong Delta is mainly organized around agricultural and small scale (food) production. The main income of people in the project area is from agriculture, such as rice and pomelo. This source of income is now being threatened by flooding and saline intrusion and occurrence of periods of drought.

Vietnam is one of the most vulnerable countries to the impacts of climate change. It's extensive lowland coastal areas which support most of the country's agriculture and aquaculture production, is particularly susceptible to flooding and saline intrusion. Both sea level rise and land subsidence are slowly increasing the risks of salinization of the coastal lowlands. In addition, drought, as experienced during the 2015-2016 El Niño Southern Oscillation (ENSO) phenomenon, will not only enhance saline intrusion but drought also has direct implications for production systems. Farmers are facing crop failures due to bad choices of crops and bad quality of seeds. In a salty drought soils farmers need seeds and planting materials which are salt and drought tolerant and can perform well under these stress circumstances.

The government realizes that there is an urgent need to prepare and plan for necessary response measures. The move towards a climate smart agriculture needs to be shaped in the context of the sustainable development of the country and region. This study will provide input in this discussion and provide strategies to deal with the urgent and immediate needs while looking a medium and long strategies to deal with saline and drought conditions.

The work in this study is a quick scan focussing on the Mekong River Delta, using international and local expertise with the aim to identify promising crop and cropping system level strategies to address salt and drought stress. Moreover, acidity and humidity stress will be addressed to certain extent also.

## 1.1 Stress

Both salinity and drought will inhibit water uptake by plants. Moreover, salinity can also be toxic to plants. Acidity stress may become a problem for agricultural crops, when soil pH-values come below 5.0. Then, the concentrations of the toxic cations ( $Mn^{2+}$  and  $Al^{3+}$ ) may increase, mainly in clay acid soils. This may lower the availability of P, Ca, Fe and Mg and cause toxicity symptoms, nutritional disorders and a disturbance of the interaction with microorganisms.

Crops differ significantly in their tolerance to concentrations of soluble salts in the root zone [1]. The difference between the tolerance of the least and the most sensitive crops may be tenfold.

The salt tolerance of a crop can best be described by plotting its relative yield as a continuous function of soil salinity [2]. This response curve could be represented by two line segments (see Figure 1): one, a tolerance plateau with a zero slope, and the other, a concentration-dependent line whose slope indicates the yield reduction per unit increase in salinity. The point at which the two lines intersect designates the threshold ( $EC_t$ ), i.e. the maximum soil salinity that does not reduce yield below that obtained under non-saline conditions.

Based on a broad survey by the USDA Salinity Laboratory at Riverside [2] a selected group of current cash crops has been categorized in the four levels of salinity tolerance, respectively 'sensitive', 'moderately sensitive', 'moderately tolerant' and 'tolerant'. This

information has been listed in the FAO Irrigation and Drainage Paper (2002), collected and is reported in a FAO-report [3].

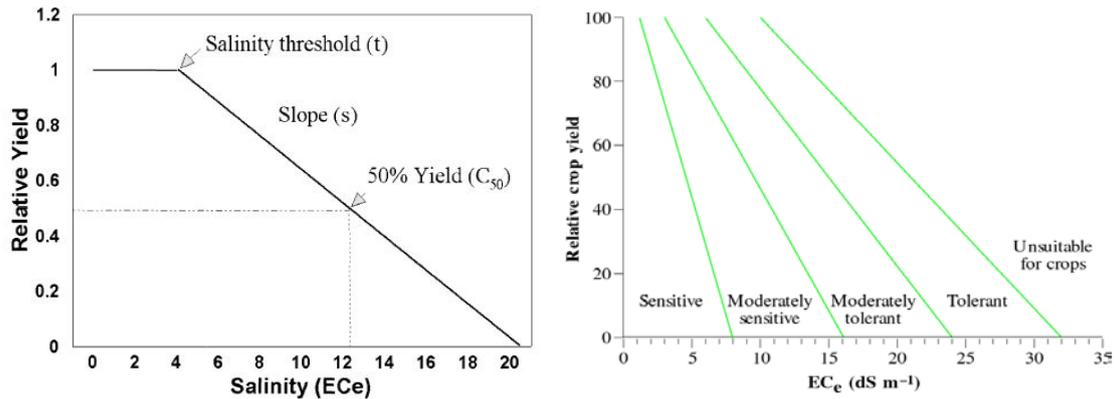


Figure 1. Salt tolerant parameters relating relative yield to increasing salinity in the root zone (left) and different categories for crops (right), (Shannon and Grieve, 1998)

## 1.2 Flora

For the design of a suitable system for Vietnam, we collected characteristics of 57 crops grown in the Mekong Delta region. The information is based on expert judgement of the project team, especially of the Vietnamese scientists, and the information from the FAO evaluated stress sensitivities (drought, salinity, acidity, heat, humidity); current area; economic value and future economic perspectives. An overview is presented in Annex I. From this list we selected 29 crops for the flora, based on tolerance for salinity and drought stress, future economic importance and sufficient scientific information from literature, and added the FAO stress-parameters (Annex II) and an innovative crop, Quinoa. In the flora we describe in more detail current tillage, farm management, and recommendations to manage stress sensitivity. The aims of the flora are:

1. to get an insight in crop responses to different stresses, which is important to have a range of crops differently responding to stresses and to select those crops that are representative and suitable to be grown in the area,
2. to use as a basis for the development of field management strategies, and
3. to select crop and management strategies to be included in the pilot phase.

The flora is structured as follows:

A table with the expert judgement information on:

- Current importance for the Mekong Delta from cultural point of view (+ or -)
- Kind of stress that may threaten each crop increasingly (as far as known)
- A rating on whether the crop is sensitive or tolerant (sensitive, moderately tolerant or tolerant)
- The FAO stress parameters, as explained in Figure 1
- The area (ha) on which it is currently grown in the Mekong Delta
- The (estimated) current economic value, and
- The future economic perspective for the Mekong (high, moderate or low)

Then, information is presented on:

- Current tillage
  - o Way of planting
  - o Use of chemicals / pesticides, etc.
- Management practices
  - o Land preparation
  - o Intercropping
  - o Irrigation weed control
- Recommendations
  - o How to deal with stress

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## 2 Common bean

Latin name:	<i>Phaseolus vulgaris</i>
Vernacular names:	Bean
Kind of stress	Drought/Salinity
Sensitivity	Sensitive
FAO-Threshold value (EC, dS/m)	1.0
FAO % Yield decrease (slope, % per dS/m)	19
FAO rating	S
Area (ha):	9,172.40
Use:	vegetables
Importance for Mekong Delta:	-
(current economic value in Mekong delta)	Low
Future potential for Mekong Delta:	Low

### Current tillage:

Ordinary propagation is by seed: plant distance for bush cultivars in sole cropping is 30-45 cm between the rows and 30 cm in the rows, but wider spacing to 75-90 x 10-15 cm makes weeding easier. Regarding climbing beans, 4-6 seeds are usually sown together in hills spaced 1 m apart at a depth of 3-6 cm. Flat cultivation is preferred. Harvest starts 7-8 weeks after sowing in early cultivars and pods should be picked every 3-4 days; large-scale crops are harvested mechanically. Common bean is a short-day plant, preferably grown within 17.5-25°C and interesting because of its ability to fixate nitrogen. A moderate well distributed rainfall is required (300-400 mm per crop cycle), but dry weather during harvest is crucial. Common beans are sensitive to night frost. [4]

### Management practices:

In rotations, plant beans are grown after cereal crops such as maize or sorghum, rather than after soybean or sunflowers, to avoid diseases [5].

Common bean can be grown rain-fed or irrigated (in semi-arid regions) [4].

Up to three weedings may be required before the crop canopy fully covers the ground. Avoid weeding after flowering, or keep it to a minimum [5].

### Recommendations:

Drought or waterlogging is detrimental. Suitable soil types range from light to moderately heavy and peaty soils with near-neutral pH and good drainage [4].

Bean is an extremely salt sensitive species, but genetic variability in salt tolerance is shown among bean cultivars [6].

Some wild species that can be used in breeding show possible Na<sup>+</sup> exclusion mechanisms conferring to salt tolerance.

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## 3 Cabbage

Latin name:	<i>Brassica oleracea</i> L.
Vernacular names:	Cabbage
Kind of stress	Drought/Salinity
Sensitivity	Sensitive
FAO-Threshold value (EC, dS/m)	1.8
FAO % Yield decrease (slope, % per dS/m)	9.7
FAO rating	MS
Area (ha):	-
Use:	vegetables
Importance for Mekong Delta:	-
(current economic value in mekong delta)	Low
Future potential for Mekong Delta:	Low

### Current tillage:

In general Brassica crops are grown from seed, though propagation by cuttings is sometimes practised in tropical areas [7]. Cabbage can be grown both as winter crop and as summer crop during the rainy season.

Land is prepared by ploughing it 3 to 4 times and the crop grows in the arrangement of ridges and furrow; seedlings are germinated in a nursery bed and transplanted after 3-4 weeks. Spacing for the early crop is 45x45 cm and the late crop it is 60x60 cm. Harvesting is done when heads are firm [8].

### Management practices:

The interval between two irrigations depends upon climate, soil and plant growth [8].

For weed control, Oxyfluorfen can be applied before and after transplanting. S-metolachlor can be applied after transplanting [9].

Cabbages grown with intercropping systems are more productive and profitable than sole cabbage cropping and have a higher use efficiency of land and resource; intercropping system benefits from additional production of for example bean, cos lettuce, onion and leaf lettuce (NB. radish as an intercrop undermine the growth and yield of cabbage). The highest LER value is realized from the combination cabbage: leaf lettuce, but the greatest economic net income from the cabbage: cos lettuce intercropping system [10].

### Recommendations:

Soils should have good drainage. The best pH range for cabbage is between pH 5.5 to 6.5 [8]: cabbage is sensitive to soil acidity.

Growth and yield are markedly reduced due to salinity. In particular, seed germination and early seedling growth have been reported to be relatively more sensitive towards salinity. There is significant intraspecific and interspecific variation for salt tolerance among different Brassica cultivars, which needs to be overworked through selection and breeding for improving salt tolerance. Recently, complete genome sequencing of the Brassica genomes has also been initiated [11].

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## 4 Coconut

Latin name:	<i>Cocos nucifera</i> L.
Vernacular names:	Coconut
Kind of stress	Salinity
Sensitivity	Tolerant
FAO-Threshold value (EC, dS/m)	-
FAO % Yield decrease (slope, % per dS/m)	-
FAO rating	MT
Area (ha):	141,615
Use:	Industrial crops
Importance for Mekong Delta:	+
Current economic value in Mekong delta	Medium
Future potential for Mekong Delta:	High

### Current tillage:

Coconut has always been propagated by 'seed' and mostly planted at triangular or square spacing of 8x8 to 9x9 m. Seed nuts usually have a resting period of 1 month after harvesting, before being kept in a germination bed from where uniform batches can be transplanted to polythene bags or to nursery beds. Seedlings are transplanted at the age of 3-8 months. Climbing the palms and cutting the coconuts is still the method most commonly practised at harvesting. Fertilizing is often required, especially on soils that have been cultivated for many years. Mechanization is practised only on large estates. The coconut palm grows well on a wide range of soils, from coarse sand to clay, provided the soils have adequate drainage and aeration, but does best on well-drained sandy soils [12].

### Management practices:

Cash crops (rice, maize, finger millet, sweet potato, cassava) are often planted until the palms come into bearing, at least at 2 m of distance to the palms. Intercropping with banana, cocoa and pineapple is practised in some areas.

Weeding is fundamental, especially for young palms, and green manuring is usually practised to advantage.

Water shortage reduces yields, so irrigation is could be practised in dry areas, sometimes even replacing rains [12].

### Recommendations:

Coconut palm tolerates alkaline soils with pH 8 and acid soils with pH 4.5, saline and infertile soils and salt-spray conditions. Occasional inundations with sea water do not damage the palm if the soil salt content does not rise too high [12].

The coconut tree has a number of physiological adjustment mechanisms that give the species partial tolerance to drought stress and/or salt, thereby enabling it to re-vegetate salinated areas, provided that its water requirements are at least partially met [13].

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## 5 Corn, Maize

Latin name:	<i>Zea mays</i> L.
Vernacular names:	Corn, maize
Kind of stress	Humidity, salinity
Sensitivity	Sensitive, moderately tolerant
FAO-Threshold value (EC, dS/m)	1.7
FAO % Yield decrease (slope, % per dS/m)	12
FAO rating	MS
Area (ha):	38,203
Use:	Food crops
Importance for Mekong Delta:	+
Current economic value in Mekong delta	Medium
Future potential for Mekong Delta:	High

### Current tillage:

Maize is generally planted through direct seeding, but in Vietnam a transplanting technique has been adopted. It should be sown as soon as soil conditions and temperature are favourable. Seed (10-25 kg/ha) may be planted mechanically or by hand in smallholder cultivation; it may be done on hills or in rows, on flat land or on ridges (on heavy soils ridging is advisable, to improve drainage). Distance between the rows varies from 60-100 cm, implying an average plant density 20,000–80,000 plants/ha. The depth of planting is 3-6 cm, and deep sowing is recommended on light, dry soils. Ploughing is done in a usual depth of about 8-10 cm. Animal manure or fertilizers can be applied at the time of planting. The crop has a wide range of tolerance to different temperature conditions [14].

### Management practices:

Maize is particularly sensitive to weed competition during the first 4-6 weeks after emergence. Inter-row cultivation to control weeds can be done until the plants reach a height of about 1 m. Chemical weed control is gradually gaining importance; the herbicide most widely used for post-emergence spraying is 2,4-D [14]. Khan et al. (2016) tested herbicides (Stomp 330 E, Dual gold 960 EC, 2,4-D, ester) in maize hybrids (P-3025, P-32T78, P-3203) and they showed that the Dual gold 960 EC herbicide is the best one for weed suppression in maize, while maize hybrid P-3025 is the best hybrid giving maximum yield (in the study) [15].

Rotations or intercropping can be done with rain fed crops such as soybean, groundnut, cassava, sweet potato, vegetables, tobacco and cotton.

Irrigation is used in areas of low rainfall and it's relevant at the time of tasselling and fertilization, when the plant is more sensitive to moisture stress [14].

### Recommendations:

The shoot/root ratio is high, therefore the crop is sensitive to drought. Maize can be grown on a wide variety of soils, but performs best on well-drained, well-aerated, deep soils containing adequate organic matter and well supplied with available nutrients. It belongs to the group of crops that is sensitive to salinity, but differences in salt tolerance between cultivars has been proven (DK-C61-42 variety shows a better growth under salt stress) [14] [16].

## 6 Dragon fruit

Latin name:	<i>Hylocereus undatus</i> (Haw.) Britton & Rose
Vernacular names:	Dragon fruit
Kind of stress	Drought/Acidity
Sensitivity	Moderately tolerant
FAO-Threshold value (EC, dS/m)	n.a.
FAO % Yield decrease (slope, % per dS/m)	n.a.
FAO rating	M
Area (ha):	12,115.70
Use:	fruits
Importance for Mekong Delta:	++
Current economic value in Mekong delta	Medium
Future potential for Mekong Delta:	High

### Current tillage:

Plantations are usually grown from cuttings established in a protected area for several months before planting out, which occurs when they are tall enough to reach the trellis supports; before this, young plants need protection from excessive sunlight and regular irrigation to develop a good root system. Row spacing is usually at least 2 m (to allow access by machinery) and within the trellised ones, spacing is 1.5-3 m between plants. Higher densities lead to a more productive and fast-growing plantation, but the plants easily become overcrowded much sooner, so requiring regular pruning or thinning. Flowering occurs in waves during the summer with three to four waves or flushes of flowers each season; these are pollinated by bats or moths, but hand pollination is also used with self-incompatible varieties to ensure good fruit set and fruit size. The best time to harvest dragon fruit is 28-30 days after flowering (at full colour development). Full production is reached in 4-5 years (30 tons of fruit/ha). Dragon fruit prefers loamy, sandy or stony moderately saline soils with good drainage, with no more than 50% slope, and does not tolerate well high light and temperature or extremes of temperature (plantations must be in frost-free areas) [17]. Application of nutrients at reproductive and vegetative growth stages provides better yield and fruit quality [18].

### Management practices:

The amount and frequency of irrigation is strictly dependent on the soil type, climate and stage of crop development and has been reported to be an average of 5 L per plant per week in the summer season and 2.5 L per plant per week in the winter [19]. Anyway, careful irrigation management is needed during the fruit formation stages because irregular watering and soil moisture levels can provoke fruit splitting [17].

Weed management is important as weeds could compete with the crop for water and nutrients: special care should be taken to control creeping weeds (they grow easily if the crop is widely spaced) as they will entangle with the vines making removal very difficult [20].

### Recommendations:

Dragon fruits perform in a loose soil with a pH of 5.5-6.5 under. A minimal amount of shade is required to prevent bleaching of the stems and to ensure that plants are not water stressed as this reduces the crops' resistance to high light damage [17].



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## 7 Groundnut

Latin name:	<i>Arachis hypogaea</i> L.
Vernacular names:	Groundnut
Kind of stress	Humidity/Drought
Sensitivity	Moderately tolerant, Sensitive respectively
FAO-Threshold value (EC, dS/m)	3.2
FAO % Yield decrease (slope, % per dS/m)	29
FAO rating	MS
Area (ha):	13,021
Use:	Industrial crops
Importance for Mekong Delta:	+
current economic value in Mekong delta	Medium
Future potential for Mekong Delta:	High

### Current tillage:

Groundnuts are grown from seed in a seed bed preferably deep, friable and weed-free, as a rain-fed crop during the wet season or in lowland areas after rice as a second or third crop in South-East Asia. Plant densities are about 200,000-250,000 plants/ha for the short-season Spanish cultivars, and near 100,000 to 125,000 plants/ha for the Australian ones. Generally, cultivation is in rows with a plant of about 40-30x20 cm. They are harvested, usually by hand, in average 85-113 days after sowing. Yield of pods is 2.5-3.0 t/ha for Vietnam. Optimum mean daily temperature for growth is 30°C, while growth ceases at 15°C [21].

### Management practices:

Groundnuts can be grown as a sole crop or intercropped with maize, soybean and cassava. In some areas, they can be grown under perennial tree crops such as coconut, oil palm or rubber.

In South-East Asia, weeding is done manually, but there is a range of pre-emergence and post-emergence herbicides that can be used to control grasses and many broad-leaf weeds.

Water well distributed through the growing season in a range of 500 and 600 mm allows to achieve a satisfactory production [21].

### Recommendations:

Groundnut is also mentioned to be a drought-tolerant species and can withstand severe lack of water, though yield is generally reduced. Plants grow and develop adequately on heavier clay soils with a pH in the range 5.5-6.5 [21].

## 8 Jack fruit

Latin name:	<i>Artocarpus heterophyllus</i> Lam.
Vernacular names:	Jack fruit
Kind of stress	Drought
Sensitivity	Moderately tolerant
FAO-Threshold value (EC, dS/m)	n.a.
FAO % Yield decrease (slope, % per dS/m)	n.a.
FAO rating	-
Area (ha):	-
Use:	Fruits
Importance for Mekong Delta:	+
Current economic value in Mekong delta	Low
Future potential for Mekong Delta:	Medium

### Current tillage:

Propagation is generally by seeds, with germination that begins within 10 days and it's almost completely achieved within 35-40 days after sowing. Seedlings are best raised under shade (50-70% of full light intensity) and they should be transplanted before the roots grow outside the pot (less than one year old). Orchard trees are spaced 8-12 m apart in square or hexagonal patterns; the usual density is 100-120 trees/ha. The best planting time is at the onset of the rainy season. The change in skin colour from pale green to greenish/brownish- yellow is the sign of fruit maturity, as well as the emission of a characteristic odour and flattening of the spines, which become wider-spaced. The stalk is cut with a sharp knife and the fruit carefully lowered to the ground. Average yield is about 70-100 kg/tree per year [22].

### Management practices:

Jackfruit can be occasionally planted as an intercrop, for example in coconut groves or in durian. Young jackfruit orchards may be intercropped with annual cash crops such as banana, sweet corn and groundnut. Annual rainfall should be 1500 mm or more, but additional watering may be needed during the first two years as well as mulching, which helps to conserve moisture during the dry season [22].

### Recommendations:

Warm and humid climates below 1000 masl are proper for jackfruit. The tree can be grown on different types of soil but performs best on deep, well-drained, alluvial, sandy or clay loam soils with pH 6.0-7.5; in fact, it has poor cold, drought and flooding tolerance, but moderate wind and salinity tolerance. It is recommended to fertilize twice a year, at the onset and before the end of the rainy season [22]. Jackfruit tolerates 3–4 months of drought. However, it does best with even and continuous soil moisture [23].



## 9 Longan tree

Latin name:	<i>Dimocarpus longan</i> Lour.
Vernacular names:	longan tree
Kind of stress	Drought/salinity
Sensitivity	Relatively sensitive, depending on soil type
FAO-Threshold value (EC, dS/m)	n.a.
FAO % Yield decrease (slope, % per dS/m)	n.a.
FAO rating	-
Area (ha):	28,350
Use:	Fruits
Importance for Mekong Delta:	++
Current economic value in Mekong delta	Medium
Future potential for Mekong Delta:	High

### Current tillage:

Propagation by seed is not recommended because seedlings take a long time to bear fruit (7-8 years) and the planting material is not true to type. Among the vegetative propagations, air layering (marcottage) is the most popular one. Trees are best planted at the beginning of the wet season [24]. Grafting can also be used, and it uses less planting material than air-layering. Moreover, it is reported that grafted trees are more drought- and wind-resistant, but only little experimental evidence for this is available. However, grafting has some disadvantages: it is not as easy to realise as air-layering, and it requires growing of seedling rootstocks. Moreover, grafted trees take longer to develop to the stage where they can be planted out. There is not much information about the graft compatibility between different cultivars, and the impact on production and fruit quality [25]. Animal manure and lime usually are applied before planting. As some digestion period is needed, planting holes of 60x60x60 cm are dug about two weeks prior to planting and provided by the manure and lime. Tree spacing varies from 6x 6m to 12x12 m, giving tree densities ranging from 70 to 300 trees/ha [24]. Growers generally use a mixture of organic and chemical fertilizers, but the source of the fertilizer does not seem to affect the production. The effect of the timing of fertilizer application on cropping not settled yet. Crop nutrient removal data should be used for estimating fertilizer requirements [25].

### Management practices:

Mini-sprinklers with micro-spray features are recommended to use for the first 2 years to limit water throw. One row of trickle tape can be sufficient for young trees, with a second line installed after 3 or 4 years. In the absence of irrigation, water conservation can be supported by mulching and cover crops, even if new orchards should be irrigated [25]. Mulching is recommended and, if applied correctly, under-tree mulching also assists weed control [24].

### Recommendations:

Any rainfall outside 1200-1400 mm requires irrigation of water [24]. The longan thrives best on a rich sandy loam and on moderately acid, somewhat organic, sand. It grows to a large size and bears heavily fruits [26].

Salinity, as measured by electrical conductivity, EC<sub>w</sub>, should not exceed 0.5 dS/m or 320 mg/l of soluble salts, implying that longan is relatively sensitive to salinity. The watering system should be capable of delivering water to the major root-zone, which could be 1.5 m deep and extend from the trunk to just past the dripline of the canopy [25].

# 10 Lotus

Latin name:	<i>Nelumbo nucifera</i> Gaertner
Vernacular names:	(sacred) Lotus
Kind of stress	Humidity/Acidity
Sensitivity	Tolerant
FAO-Threshold value (EC, dS/m)	n.a.
FAO % Yield decrease (slope, % per dS/m)	n.a.
FAO rating	-
Area (ha):	-
Use:	fruits
Importance for Mekong Delta:	+
(current economic value in Mekong delta)	Low
Future potential for Mekong Delta:	Medium

## Current tillage:

Pieces of rhizomes (commonly used as planting material) are planted with the buds just above the mud under about 1 m of water (45 kg of pieces of rhizomes/1 ha). Plants can be also grown by seed (10 kg of seeds/ 1 ha), but it takes more time to produce rhizomes of tradeable size; seedlings are raised (from seeds) in nursery beds and planted out after about 2 months. Harvesting follows the rainy season. Rhizomes are dug up by hand after the ponds are drained (if they are cultivated in ponds). Flower buds are picked 2-3 days before opening and fruits are collected when ripe. The natural habitat for lotus is freshwater bodies. Lotus grows in old mining pools, natural or man-made lakes, canals and ponds. Rhizomes are not reached by frost that would be detrimental, because they lie deep in the mud under water [27].

## Management practices:

Water weeds like *Eichhornia crassipes* and *Typha spp.* compete with lotus plants, therefore they must be removed [27].

## Recommendations:

According to Liu et al. (2014), 'Welcoming Guests' cultivar is the most to salt stress, while 'Hunan Lotus' is the most sensitive one [28].



# 11 Mango

Latin name:	<i>Mangifera indica</i> L.
Vernacular names:	Mango
Kind of stress	Drought/salinity
Sensitivity	Moderately tolerant
FAO-Threshold value (EC, dS/m)	-
FAO % Yield decrease (slope, % per dS/m)	-
FAO rating	S
Area (ha):	38,773
Use:	fruit
Importance for Mekong Delta:	++
(current economic value in Mekong delta)	High
Future potential for Mekong Delta:	High

## Current tillage:

Polyembryonic cultivars can be used for propagation from seed, but budding and grafting are more common. Grafting can be done at any rootstock age, and the earliest moment is in about 8 weeks from sowing [29].

In the low-latitude tropics, flowering is initiated after a period of water stress of at least six weeks and is ended by rain or irrigation, while in the high-latitude tropics and subtropics flower buds are initiated during the cool winter months (<15 degrees C) [30]. The period of differentiation varies between cultivars and the local climatic conditions. Mangoes generally reach maturity in 4-5 months from flowering, they are harvested at a mature green stage and kept for normal ripening; depending on the variety and environmental conditions, they take 6–10 days to ripen under ambient temperature [31].

## Management practices:

The preferred methods of irrigation are micro-sprinklers and drip irrigation [30]. Irrigation also widens the scope for intercropping (for example, with papaya, banana, pineapple or vegetables) during the establishment phase. When the trees are big enough to produce a substantial crop, irrigation is stopped, or just interrupted long enough to force quiescence to flower initiation [29].

A field experiment conducted for two years to evaluate the effect of four herbicides (Glyphosate, Paraquat, Atrazine, and Sencor) on weeds in a mango nursery showed that higher concentrations of atrazine and sencor were the most effective but generally, all the herbicides decreased the weed population and their dry weight [32].

## Recommendations:

Mango trees are drought-tolerant and do not seem to suffer from occasional flooding. A deep (rooting depth 2.5 m) but rather poor soil is preferred; easy access to water and nutrients tends to stimulate growth at the expense of flowering. A pH is preferred in the range of 5.5-7 [29]. Mango is sensitive to soil salinity at younger stage, even if some mango genotypes are salt tolerant to some degree but knowledge on the exact mechanism and level of salt tolerance in those genotypes is still lacking [33].

Gomera-1 is the most adaptable rootstock to saline conditions, making it feasible for use in areas with low water quality [34].



## 12 Mangosteen

Latin name:	<i>Garcinia mangostana</i> L.
Vernacular names:	mangosteen
Kind of stress	Drought/Salinity
Sensitivity	Moderately tolerant
FAO-Threshold value (EC, dS/m)	-
FAO % Yield decrease (slope, % per dS/m)	-
FAO rating	-
Area (ha):	-
Use:	Fruits
Importance for Mekong Delta:	+
Current economic value in Mekong delta	Low
Future potential for Mekong Delta:	Medium

### Current tillage:

Mangosteen is generally propagated from seed, but grafting on mangosteen seedlings can also easily and successfully be done. Mangosteen requires an area of 40 to 80 m<sup>2</sup> per tree for growth, which is extremely slow (especially below 20°C and above 38-40°C): a 60 cm tall seedling with one or two pairs of laterals takes about 2 years to raise. Fruits ripen over a period of 6-12 weeks, and they need to be picked every 2-3 days (when turned to light red) to obtain the top quality. The long ripening season implies a high cost of picking, which appears to be a major constraint for commercialization of the crop [35]. Light red fruit ripens in four to six days, then the fruit turns to dark purple (full ripe stage). Fruiting season in the South of Vietnam is from May to August (peak period June to July) while in Central Vietnam (Hue), mangosteen bears fruit in January-February [36].

### Management practices:

Young plants have to be shaded during the first 2-4 years, which can gradually be reduced. This is a common practice and similar to that of other fruit trees like durian, langsat, rambutan or coconut. The plant is very vulnerable to weeds because of its slow growth; to avoid weeding, a heavy mulch around the tree can be done. Trickle irrigation or the use of small under-the-tree sprinklers may be ideal, given that mangosteen benefits from supplementary irrigation, even in quite wet areas [35].

### Recommendations:

Mangosteen thrives up to 1000 m elevation in conditions of high temperature, high humidity, a short dry season and an uninterrupted water supply. Shelter is required throughout the trees lifetime. An assured year-round supply of water is essential. In spite of the weak root system the tree tolerates heavy soils which impede water movement, provided transpiration is limited by sheltering and high humidity. Under dry conditions irrigation is needed at small soil moisture deficits, and thick mulches are very beneficial [35].



## 13 Mung bean

Latin name:	<i>Vigna radiata</i> (L.) R. Wilczek
Vernacular names:	mung bean
Kind of stress	Drought/Salinity
Sensitivity	Moderately tolerant, Sensitive respectively
FAO-Threshold value (EC, dS/m)	1.8
FAO % Yield decrease (slope, % per dS/m)	20.7
FAO rating	S
Area (ha):	7,758.60
Use:	Industrial crop
Importance for Mekong Delta:	+
Current economic value in Mekong delta	Low
Future potential for Mekong Delta:	Medium

### Current tillage:

Propagation is by seeds, which may sprout in the pod under very humid conditions, and broadcasted or dibbled on hills or in rows. With early-maturing cultivars (60-75 days), maximum yields are obtained at plant densities of 300.000–400.000 plants/ha, though late-maturing traditional ones generally need wider spacing. Cultivars differ considerably in harvesting (the most expensive single operation) efficiency, depending on position (above or within canopy) and size of pods [37].

### Management practices:

Mung bean is often grown as mixed crop or intercrop. In monsoon tropics, mung bean is mainly grown as rainy season crop on dryland or as dry-season crop after the monsoon in rice-based systems on wetland, making use of residual moisture or supplementary irrigation. When adequate early rains occur, an early-season crop before the monsoon can be grown [37].

Among different weed management practices, interculturing and hand weeding (at 20 and 40 DAS) appears most efficient with lowest weed dry weight and higher weed control efficiency. Pre-emergence application of Pendimethalin @ 500 g/ha or Imazethapyr 75 g/ha, followed by interculturing and hand weeding at 30 DAS are very effective in weed control [38]. The cropping systems 1:2 pigeon pea [*Cajanus cajan* (L) millsp] green gram [*Vigna radiata* (L) Hepp] seems to have higher grain yields and economically feasible net returns, so that farmers can integrate 1:2 pigeonpea-green gram intercropping system without reducing spacing of the main crop and apply previous crop residues as mulch if possible; this not only conserves soil moisture during a dry spell period, but also enhances nutrients uptake under rain fed conditions [39].

### Recommendations:

Mung bean is well adapted to red sandy loam soils, it does reasonably well on sandy soils, if not too exhausted, it's drought-tolerant though it doesn't adapt well on wet, poor drained soils. It will give reasonable yields with as little as 650 mm of yearly rainfall. However, heavy rainfall results in increased vegetative growth with reduced pod setting and development [37]. Plants seem to be more resistant to salinity in an early vegetative stage than in late vegetative and reproductive stage. Salt stress, high temperature and salinity-induced osmotic stress grossly decrease plant growth and yield during summer, but less during the spring season. They found that the tolerant variety "Pusa vishal" exhibited less reduction in plant productivity than other varieties [40].

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# 14 Orange

Latin name:	<i>Citrus sinensis</i> (L.) Osbeck
Vernacular names:	Orange
Kind of stress	Humidity/salinity
Sensitivity	Sensitive, Moderately tolerant respectively
FAO-Threshold value (EC, dS/m)	1.3
FAO % Yield decrease (slope, % per dS/m)	13.1
FAO rating	S
Area (ha):	32.939,20
Use:	Fruit
Importance for Mekong Delta:	+
Current economic value in Mekong delta	Medium
Future potential for Mekong Delta:	High

## Current tillage:

The preferred propagation method for sweet orange is budding using one of the many hundred rootstocks. Planting density are among 200 to 400 trees/ha [41]. Land preparation is commonly by hand on sloping areas or by small tractor on flat land; then, holes 60(diameter)x 40(deep) cm are manually drilled at a spacing of 3x3 to 6x6 m. Orange matures almost 6-9 months after bloom. The fruit is picked with an upward twisting action or cut from the tree. [36] Growth can occur between 13 and 40°C, and summer months should have average temperatures in excess of 15.5°C. Oranges prefer dry summers [41].

## Management practices:

If the soil is not well drained, the trees are planted on a mound of 10 cm high to prevent waterlogging. After the soil has settled, the plant must still be above field level, to reduce the risk of foot rot [41].

Sweet oranges require well-distributed rainfall of approximately 850 mm [41]. In northern Vietnam, rainfall is well distributed for about 1500 to 1700 mm a year, so supplemental irrigation is not needed since there are occasional rains even in the dry season. Moisture must be maintained by watering if there is a lack of seasonal rainfall [36].

Various leguminous crops are used as cover crops, to protect the soil against erosion in wet areas, such as *Pueraria phaseoloides* (tropical kudzu), which is very suitable, a fast grower that fixes more nitrogen than is needed for good growth of the trees. *Centrosema* sp. and *Flemingia* sp. are also useful cover crops but fix less nitrogen than kudzu [41].

## Recommendations:

Drought tolerance is dependent on variety. Sweet oranges are generally sensitive to waterlogging and are unsuited to high-humid tropics due to high disease incidence and poor skin quality. Rangpur rootstock is tolerant to drought, but it is susceptible to nematodes and blight. Sour orange is an excellent rootstock for fresh fruit production in areas free of tristeza virus. Shelter-belts are advisable for wind-prone areas. Flat sites are generally preferred on light, well-drained soils with a pH range 5-8 [41].

Tetraploid Dez orange *Citrus sinensis* (L.) Osb.) exhibited a better adaptation to salinity stress than its corresponding diploid in its seedling stage [42].

# 15 Papaya

Latin name:	<i>Carica papaya</i> L.
Vernacular names:	papaya, pawpaw
Kind of stress	Drought/Salinity
Sensitivity	Moderately tolerant
FAO-Threshold value (EC, dS/m)	-
FAO % Yield decrease (slope, % per dS/m)	-
FAO rating	MS
Area (ha):	-
Use:	fruits
Importance for Mekong Delta:	+
Current economic value in Mekong delta	Low
Future potential for Mekong Delta:	Medium

## Current tillage:

Papaya is propagated by seed and germination is above ground and takes 2-3 weeks. Seedlings grow rapidly and pollination is basically by wind, aided by small insects like thrips. For fresh fruit and papain production it is suggested to renew the plantation every 3 years. A high initial growth rate leads to early flowering (within 6 months from sowing) and fruiting (fruit maturing 4-5 months after flowering). Field spacing is in the order of 3-2.50 x 2-1.60 m, giving densities of 1667-2500 plants/ha. Traces of yellow colour on the fruit indicates its readiness for harvesting; cool and cloudy weather delays fruit ripening and depresses fruit quality. Papaya grows well in warm areas (21-33°C) with adequate rainfall: when evenly distributed, annual rainfall of 1200 mm is sufficient if water conservation practices are employed. Plantations should be located in sheltered environments or surrounded by windbreaks [43].

## Management practices:

Papaya can be planted as an intercrop under coconut or as cash crop between young fruit trees such as mango, citrus or rambutan.

Papaya suffers from severe competition with weeds, if they are only slashed: herbicides with a wider spectrum of weed control (Diuron, Oxyfluorfen) could injure young plants, but they can be used later in development.

Irrigation is required to minimize flower abortion and to maintain growth during the dry season: watering once a week is recommended as guideline if no data on crop water use, soil depth and moisture retention are available [43].

## Recommendations:

Papaya thrives in light, well-drained soils rich in organic matter with soil pH of 6.0-6.5, though it can tolerate any kind of soil if well-drained and not too dry (roots are very sensitive to waterlogging and even short periods of flooding can kill the plants) [43].

For best performance of a crop it is necessary to adopt managements strategies, such as the use of tolerant cultivars and a well-balanced nutrient composition when irrigated with saline water, as described by [44].

# 16 Pineapple

Latin name:	<i>Ananas comosus</i>
Vernacular names:	Pineapple
Kind of stress	Drought/Acidity
Sensitivity	Tolerant
FAO-Threshold value (EC, dS/m)	-
FAO % Yield decrease (slope, % per dS/m)	-
FAO rating	MS
Area (ha):	25,370
Use:	Fruits
Importance for Mekong Delta:	++
Current economic value in Mekong delta	Medium
Future potential for Mekong Delta:	High

## Current tillage:

Pineapple is propagated by crowns, slips (the preferred material) or suckers. Planting is usually in double rows with a sufficiently wide path between the double rows to allow for field operations: the recommended spacing is the size of (90 + 60) cm x 30 cm. Harvesting is done by hand, with crown and peduncle chopped off at the same time [45].

## Management practices:

Where rainfall is not well distributed, irrigation maintains growth and so advances fruiting. A drip line between each pair of rows is ideal; it can also be used for fertilization. In a suitable tropical climate, growth rate mainly depends on a steady moisture supply to the shallow root zone, so it is needed to have an adequate drainage, a careful weed control and a polythene mulch over each row. Systemic pre- and post-emergence herbicides are recommended for the control of weeds. Black polythene strips can be laid through them to suppresses weed growth, the polythene cuts down erosion, warms the soil and reduces leaching, in addition to conserving moisture. Hand weeding between each pair of rows is necessary, even with mulching [45].

## Recommendations:

The temperature range of growing areas is 23-32°C. However, the plant does not tolerate frost and the fruit is sensitive to sunburn. The plant is very drought-resistant, but the root system is shallow so that under dry conditions growth quickly stagnates. A well-drained sandy loam is preferred, with a high organic matter content and pH 4.5-6.5 [45].

Fruit weight and size declines with increasing salinity and will affect the quality of pineapple fruits; the firmness of the fruit decreases significantly [46].



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## 17 Plumbrassic

Latin name:	<i>Prunus domestica</i> L.
Vernacular names:	Plumbrassic
Kind of stress	Drought
Sensitivity	Moderately tolerant
FAO-Threshold value (EC, dS/m)	2.6
FAO % Yield decrease (slope, % per dS/m)	31
FAO rating	MS
Area (ha):	-
Use:	Fruits
Importance for Mekong Delta:	+
Current economic value in Mekong delta	Low
Future potential for Mekong Delta:	Medium

### Current tillage:

Plum cultivars are propagated by budding onto a rootstock such as *P. persica*, *P. mume*, *P. dulcis* and *P. cerasifera*. Trees usually bear their first appreciable crop the third or fourth year after planting. Fresh market plums continue to ripen after picking, and they should be left on the tree until they achieve maturity, which is indicated by the development of yellow or amber colour in the flesh [47].

### Management practices:

*P. domestica* needs to be cut (headed) back in the first 2 years to force growth of lateral branches for scaffold development, but pruning should be minimal until the tree bears fruit and it generally consists of thinning out fruiting wood to reduce crop load and to stimulate renewal of shoots for future crops. Otherwise, an insufficient removal of fruiting wood would lead to excessive fruit set and high thinning costs.

A proper weed management is needed to reduce competition for nutrients and moisture, consequently increasing fruit size.

Irrigation is beneficial especially in dry climates or in dry years [47].

### Recommendations:

Plum trees grow well in a wide range of soil types with pH 5.5-6.5 and tolerate moist soil. Plum is used as rootstocks in humid and heavy soils [47].

Plant-damaging concentrations of B and Cl in treated effluents used for irrigation could damage the performance of plum (*Prunus domestica* L.) trees, so the use of rootstocks that tolerate the damaging ingredients of the water and also giving right horticultural traits might reduce the injury. Zilkah et al. (2011) grafted commercial plum rootstocks of 'GF 677', 'Hansen 536', 'Myran', 'S.2729', 'Mariana', 'Citation', and 'Ferciana' with the plum scion 'Sungold'. The results showed that 'Mariana' and 'Myran' were more tolerant according to the leaf B accumulation parameter than according to the leaf damage parameter. Moreover, 'Mariana' was categorised as more tolerant and 'Hansen' more sensitive by the leaf Cl accumulation parameter than by the leaf damage parameter. Overall, 'Fersiana' was considerably the most tolerant and 'Citation' the most sensitive of the rootstocks to B and Cl phytotoxicity [48].

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## 18 Pummelo

Latin name:	<i>Citrus maxima</i> (Burman) Merr.
Vernacular names:	Pummelo, pomelo
Kind of stress	Drought/Salinity
Sensitivity	Moderately tolerant
FAO-Threshold value (EC, dS/m)	-
FAO % Yield decrease (slope, % per dS/m)	-
FAO rating	
Area (ha):	25,173
Use:	Fruits
Importance for Mekong Delta:	++
Current economic value in Mekong delta	High
Future potential for Mekong Delta:	High

### Current tillage:

Propagation method in South-East Asia is air layering. Budding is recommended and pummelo seedlings (spontaneous ones are rare) of uniform populations can be used as rootstocks. The main flowering period follows the onset of the monsoon rains, unless it is brought forward by irrigation (bloom in January-February). Fruit matures 7-10 months after flowering. Yields hugely depend on cultivar and environment. The tree prefers deep, medium-textured and fertile soils [49].

### Management practices:

Young trees are pruned to leave three main framework branches, with the lowest at least 30-40 cm off the ground, but they also need some pruning in later years.

A cover crop partially suppresses weeds, but in the rainy season weeds need to be slashed: early in the dry season the orchard is hoed or treated with herbicide. Mulching under the trees with rice straw or other material is strongly recommended to maintain root growth in the topsoil, to reduce water loss from the soil, to increase soil organic matter and structure, to reduce extremes of soil temperature and to suppress weed growth. Irrigation is important from before flowering until after harvest to supplement rain. During the subsequent dry period, irrigation can be delayed until the trees show signs of wilting [49].

### Recommendations:

Drought periods longer than 30 days or temperatures below 25 °C are needed to induce a substantial number of flower buds [49].

Rough lemon rootstocks seem to be very drought tolerant because of their extensive and deep root systems. Some studies also indicate that using tetraploid rootstocks increases the drought tolerance in comparison to their diploid clones in citrus. Citrus rootstocks from different species may considerably vary in the extent of Cl<sup>-</sup> and/or Na<sup>+</sup> accumulated in the foliage of grafted trees. Salt stress mainly present in *Citrus reticulata* (Mandarins) and *C. maxima* (Pummelo's). For instance, in Fino lemon trees, sour orange rootstock is considered a good Cl<sup>-</sup> and Na<sup>+</sup> excluder, whereas the *Citrus macrophylla* rootstock is a Cl<sup>-</sup> and Na<sup>+</sup> accumulator. Tuzcu Cleopatra mandarin, Rangpur lime, Gou Tou, and Antalya Cleopatra mandarin were found to be the most tolerant to salt stress. This offers the possibility of using rootstocks from mandarins and pummelo's for other citrus species [50].

## 19 Rice

Latin name:	<i>Oryza sativa</i> L.
Vernacular names:	rice
Kind of stress	Drought/Salinity
Sensitivity	Sensitive, Moderately tolerant respectively
FAO-Threshold value (EC, dS/m)	3.0
FAO % Yield decrease (slope, % per dS/m)	12
FAO rating	S
Area (ha):	4,308,644
Use:	food crop
Importance for Mekong Delta:	+
Current economic value in Mekong delta	High
Future potential for Mekong Delta:	High

### Current tillage:

Rice is propagated by seed, broadcast or drilled in the field, both in dry or puddled soil, or seedlings may be grown in nurseries and then transplanted in puddled soil. The water level is kept at 0-5 cm and the use of herbicides is needed. The most common practice in the delta is dry direct seeding. In dry soil, seeds are sown after land preparation and covered with soil by using a tooth harrow. Germination takes place after heavy continuous rains. In upland rice cultivation of land is prepared during dry weather and the rice is broadcast or dibbled in with the coming of the rains. Floating rice is cultivated in areas subject to deep flooding and the seed is sown dry or wet [51].

### Management practices:

Land preparation varies, even within the lowland rain fed-rice areas:

- Wetland tillage (common in most tropical Asian countries) consists of land soaking, in which water is absorbed until the soil is saturated; the land is ploughed to a depth of 10-20 cm, better if there is 7.5-10 cm of water on the land, and harrowed: big clods of soil broken and puddled with water seems to imply a better weed control.
- Dryland tillage (the land is prepared in dry weather and rice is sown just before the rains begin). There are less labour requirements for seed-bed preparation, land preparation and transplanting. Bunding and levelling are fundamental for keeping the water on the land and maintain it at the required depth.

Rainfall variability is the foundation for subdividing the irrigated ecosystem into irrigated wet season areas, in which water may be added to the rice fields during the local wet season as a supplement to rainfall; irrigated dry season areas, where no rice crop can be grown without supplemental water.

Rice crop may be grown in rotation or intercropped with cassava, maize, groundnuts and other pulse crops; intercropping is practised in upland rice [51].

### Recommendations:

Submergence-tolerant varieties usually produce the highest yields. Yields of tidal rices vary widely; crop failure can occur in salt-affected areas. *Porteresia coarctata* wild rice is tolerant of salinity [51]. There are several traditional cultivars such as Pokkali, Nona Bokra, Cheriveruppu and Getu that are saline tolerant but possess poor agronomic characteristics. Salt tolerance from Pokkali has been introgressed in Vietnamese popular varieties at target sites. Breeding tools for this (plant material, markers) are available at IRRI (Phillippines) [52].

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## 20 Sesame

Latin name:	<i>Sesamum indicum</i> L.
Vernacular names:	Sesame
Kind of stress	Drought/salinity
Sensitivity	Moderately tolerant
FAO-Threshold value (EC, dS/m)	-
FAO % Yield decrease (slope, % per dS/m)	-
FAO rating	S
Area (ha):	24,451.60
Use:	Industrial crops
Importance for Mekong Delta:	+
Current economic value in Mekong delta	Medium
Future potential for Mekong Delta:	High

### Current tillage:

The sesame crop can be grown both as summer crop and as semi-winter crop. Sowing can be done in broadcast or line, which is preferred; 3 cm depth is enough, such as 25-35 cm row-to-row spacing and 10-20 cm plant-to-plant spacing. Seed density depends on sowing methods and seed variety:

1. in the broadcasting method, under rain fed conditions, seed density would be 6 kg/hectare; under irrigated conditions, 5 kg/hectare.
2. in row seeding, under rain fed conditions seed density would be 5 kg/hectare and under irrigated condition 4 kg/hectare.

Depending on the variety, sesame matures in 3 to 5 months. Harvesting can be started when leaves, stems and capsules begin to turn yellow [53].

### Management practices:

The land should be ploughed and harrowed repeatedly. First 15-25 days after sowing is important for weeding; irrigated sesame crops require regular weeding operations whereas rain fed crops just once or twice. Depending upon the soil type and climatic conditions, water should be provided for 7 days after sowing [53].

A proper combination of pre- and post-emergence herbicides along with seed priming could be used for weed control [54].

Legume association with Sesame could increase total productivity and enrich soil fertility: intercropping with black gram in 1:1 proportion in summer rice fallows can be recommended as an economically viable, biologically suitable and sustainable intercropping system [55].

### Recommendations:

Preferred soil pH range is 5.5 to 8.0. Saline soils are not suitable. Drought stress inhibits sesame seed germination and early seedling growth even more than salt stress. However, Moroccan genotypes (yellow and brown seeds) are more tolerant to both stresses than American genotypes (white and black seeds), which indicates that Moroccan cultivars might be selected under drought and salt stresses conditions [53].

Seedling growth was more affected by both stresses than seed germination for Moroccan cultivars. Thus, root length and/or shoot length could be relevant selection criteria in sesame breeding for drought and salt tolerance at early growth stages [56].

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## 21 Shallot

Latin name:	<i>Allium cepa</i> L. var. 'Aggregatum'
Vernacular names:	Shallot
Kind of stress	Acidity
Sensitivity	Moderately tolerant
FAO-Threshold value (EC, dS/m)	n.a.
FAO % Yield decrease (slope, % per dS/m)	n.a.
FAO rating	-
Area (ha):	-
Use:	vegetables
Importance for Mekong Delta:	+
current economic value in Mekong delta	Low
Future potential for Mekong Delta:	Medium

### Current tillage:

Shallots are commonly propagated by bulbs (from 4-5 g) stored for 3-4 months to avoid problems of dormancy. They are planted in beds 1-1.2 m wide and 0.6 m high, with furrows of 0.4-0.5 m wide between the beds. Planting distances is 18-20 cm between rows and 10-15 cm in the row.

Propagation by seed seems to lead to lower yields and quality; it requires a density of 25-50 g of seed per 3-5 m<sup>2</sup>, enough to plant 100 m<sup>2</sup>. After 5 weeks, the seedlings are transplanted to the field. Harvesting occurs after the leaves have wilted (more or less 60-70 days after planting in the tropical lowlands, and 80-100 days in the highlands) [57].

### Management practices:

In the tropics, shallots are widely grown in paddy fields after the rice crop has been harvested. During dry weather, shallot has to be irrigated frequently (daily or even twice a day) by sprinkling 3-5 mm.

Weeds are a serious problem and weeding by hand is done every 2 weeks because the lengthy growing season required for bulb onion production allows for successive flushes of weeds at different times of the year [57].

### Recommendations:

Shallots are a cool-season, frost-tolerant biennial that grows on a variety of well-drained soils. Tropical shallots require an average day temperature of 20-26°C and a day length of at least 11 hours. They can be cultivated in soil with a pH higher than 5.6, but prefer well-drained alluvial clay soil [57].

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## 22 Soursop

Latin name:	<i>Annona muricata</i> L.
Vernacular names:	Soursop
Kind of stress	Acidity/Salinity
Sensitivity	Tolerant
FAO-Threshold value (EC, dS/m)	n.a.
FAO % Yield decrease (slope, % per dS/m)	n.a.
FAO rating	-
Area (ha):	-
Use:	Fruits
Importance for Mekong Delta:	+
Current economic value in Mekong delta	Low
Future potential for Mekong Delta:	Medium

### Current tillage:

Soursop is commonly raised from seed but it can also be propagated clonally, and seeds are sown directly in the field or in a nursery bed. Within 20-30 days 85-90% have been germinated. Seedlings can be planted out after 6-8 months; halving the leaves and temporary shading are necessary for transplanted seedlings which have not been raised in containers. Spacing in orchards should be 3x4 m to 4x6 m. The soursop fruits are considered mature when their spines are set far apart and the shiny green colour turns to dull green or yellowish green and should be harvested when fully grown and still firm. Yields are generally low: one or two dozen fruit per tree per year, with each fruit weighing more than 1 kg on average. Application of manure and/or NPK fertilizer in small doses a few times each year promotes growth and fruiting. Water sprouts, interlacing and crowded branches should be removed [58].

### Management practices:

Soursop may be planted as an intercrop between larger fruit trees such as mango, avocado and santol. The area around the base of the tree should be kept free from weeds or covered with mulch to avoid dehydration of the shallow roots during the dry season. Supplementary irrigation would be beneficial in prolonged dry conditions, when the tree sheds many leaves.

Herbicides should be applied before planting to control weeds, especially grasses and twining weeds. Young trees should be protected from weed competition by hand weeding, mulching or contact herbicides [58].

### Recommendations:

Soursop cannot tolerate standing water for any length of time; on the contrary, it can tolerate dry soil conditions [58]. *A. squamosa* is more sensitive than *A. muricata* to salt stress and older seedlings of both species are more tolerant than younger seedlings [59].

## 23 Soybean

Latin name:	<i>Glycine max</i> (L.) Merrill
Vernacular names:	soybean, soyabean
Kind of stress	Drought/Salinity
Sensitivity	Moderately tolerant
FAO-Threshold value (EC, dS/m)	5.0
FAO % Yield decrease (slope, % per dS/m)	20
FAO rating	MT
Area (ha):	1,147.20
Use:	Industrial crops
Importance for Mekong Delta:	+
Current economic value in Mekong delta	Low
Future potential for Mekong Delta:	Medium

### Current tillage:

Soybeans are propagated by seed and can be sown in rows with a spacing of 25x25 or 20x20 cm in fields without tillage in rice stubble after each harvest, while in tilled fields the rows are 40-50 cm apart. Within rows, the seeds are either drilled or planted 10 cm apart. The cycle from sowing to maturity takes about 65-150 days. Temperatures below 21°C and above 32°C can reduce floral initiation and pod set. Harvested plants can be cut near the ground or directly pulled with their roots when most leaves have matured and turned yellow. Grain soybeans are harvested when the pods have turned brown or black, vegetable soybeans are harvested when the pods are still green but the seeds fill the pod [60].

### Management practices:

Soybeans are cultivated as a sole crop but also in various intercropping systems with maize, cassava, sorghum, banana, sugarcane, rubber, oil palm, coconut and fruit trees. Soybean requires 7.6 mm/day of water, 500 mm in a season for a good yield: irrigations at flowering and during seed filling are fundamental.

Weed control is crucial (timing and frequency differs with season, cultivar and locality) [60]. Little or no reduction in yield occurs if soybeans are kept weed free for the first four weeks: this is the critical period for weed competition in soybeans, in which appropriate weed control is a must to obtain adequate grain yields. Herbicides alone or in combination with hand weeding have been found to be quite effective in controlling weeds [61]. Higher economic yields may be achieved in soybean by applying early post-emergence Imazethapyr at the rate of 100g ha<sup>-1</sup> at 15 DAS [62].

### Recommendations:

pH 6.0-6.5 allows optimum yield, though lower values are damaging.

Drought stress during flowering reduces pod set but it is more harmful at pod-filling stage. Soybeans can tolerate brief waterlogging but weathering of seed can become a serious problem in the rainy season [60].

The cultivar Lee can be considered more tolerant to salinity than Coiquitt and Clark 63 [63]. Three soybean varieties have been compared under salt stress: wild *G. soja* (W8), semi-wild *G. gracilis* (SW18), and the cultivated salt-sensitive *G. max* (cv. Melrose). It appeared that shoot and root lengths and biomass (either shoot or root dry weights) were significantly higher for the W8 genotype than for the other two. The W8 genotype performed better in terms of seedling growth, photosynthetic characteristics, and physiological indexes [64].

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## 24 Sugar cane

Latin name:	<i>Saccharum officinarum</i> L.
Vernacular names:	Sugar cane
Kind of stress	Acidity/Salinity/drought
Sensitivity	Moderately tolerant
FAO-Threshold value (EC, dS/m)	1.7
FAO % Yield decrease (slope, % per dS/m)	5.9
FAO rating	T
Area (ha):	50,348.70
Use:	industrial crops
Importance for Mekong Delta:	+
Current economic value in Mekong delta	Medium
Future potential for Mekong Delta:	High

### Current tillage:

Sugarcane is propagated by cuttings of mature stalks, which consist of either top cuttings, seed sets taken from the upper part of the stalks, or stem cuttings, seed sets taken from plants in special nurseries at about 6-8 months of age (June-July, November) [65]. True seed is only used for breeding new cultivars; seeds are planted (January) in a narrow furrow with good tillage and they are covered with a thin layer of soil from the inter-row (in wet sites, planting may be on the top of the ridge between the furrows). Planting could also be mechanical: stalks are cut into pieces, disinfected, fertilized, planted and covered with soil in a single operation.

Mature cane is cut and loaded manually, hand-cut and grab-loaded or loaded in bundles by chains pulled by a tractor. Burning before cutting is not now usually practised. Sugarcane is a short-day plant with an optimal day length of 12-14 hours, which grow well under full sunlight and with an average rainfall of 1800-2500 mm/year. Most suitable soils for sugarcane are deep, friable and well-drained ones, with a pH of 5-8. During maturation, the cane requires a dry spell to reduce growth and induce sugar accumulation [66].

### Management practices:

Weed control is carried out manually, chemically and mechanically, at 3-4-week intervals with 3-4 weeding per season manually. Chemical weeding may involve the use of: diuron, ametryne, atrazine, paraquat or asulam, while mechanical weed control can be carried out by tractor or bullock-drawn cultivators.

Irrigation water, if necessary, is supplied every 2-4 weeks in furrows with a depth of 25-30 cm and a spacing of 1.10-1.30 m made for hand-cultivated cane.

Sugarcane is usually planted as sole crop, but in areas with light soils and sufficient irrigation water, it is intercropped, for example, with maize, groundnut or soybean: in such cases, the intercrops are planted on the ridges and the cane is planted 3-4 weeks later in the furrows. As suggested by CABI, a common rotation is two consecutive cane crops (planted cane and first ratoon), followed by maize, soybean or groundnut, and rice [66].

### Recommendations:

Some cultivars can stand relatively high soil salinity [66]. (Most) cultivars are sensitive to salt and drought. Some germplasm is known to be used in breeding (wild species) for drought tolerance. Some focus is on oxidative stress alleviation.

## 25 Sunflower

Latin name:	<i>Helianthus annuus</i> L.
Vernacular names:	Sunflower
Kind of stress	Drought
Sensitivity	Moderately tolerant
FAO-Threshold value (EC, dS/m)	4.8
FAO % Yield decrease (slope, % per dS/m)	5.0
FAO rating	MT
Area (ha):	-
Use:	Industrial crops
Importance for Mekong Delta:	-
Current economic value in Mekong delta	Low
Future potential for Mekong Delta:	Low

### Current tillage:

Sunflower is sown directly in the field at a depth of 3-8 cm in a medium fine seed-bed, free from weeds. Optimal planting dates are from February to November [67]. With mechanical planting are involved 3-8 kg/ha of seeds (depending on seed size) and common used spacing are 60-75 cm between rows and 20-30 cm within the row. Optimum final plant densities are 15,000–30,000 plants/ha under rain fed and 40,000–60,000 for irrigated sunflower crops (it depends on the environment and the cultivar). Manual harvesting is done when the heads become yellow-brown and seed moisture content is 10-12% (about 120-160 days after planting for tall and 80-110 days for dwarf cultivars), and involves cutting the heads and drying them on platforms or threshing floors for 6-7 days in the sun before manual or mechanical threshing and winnowing [68].

### Management practices:

If a soil crust has formed after rain, deep-seeded plants may hardly break through the crust, so harrowing the crust before the emerging of seedlings is recommended.

During the growing period, irrigation is needed at least once a week, mainly during the first month of the flower's development [67].

In pre-emergence applications, mixtures with s-Metolachlor *give* best control of grasses, followed by mixtures with Flufenacet (only Linuron in the case of *Polygonum lapa-thifolium* L. didn't show positive results). In presence of mixed infestations (grasses + broadleaves), s-Metolachlor + Aclonifen and s-Metolachlor + Oxyfluorfen *seem* to be the best options for pre-emergence weed control. In post-emergence applications, Aclonifen shows a satisfactory efficacy against broadleaves and its weed control spectrum could be completed by mixtures with Quizalofop-ethyl. However, this option seems to be advisable only with high grasses infestation levels [69].

### Recommendations:

Sunflowers are extremely drought tolerant [67].

Pre-sowing sunflower seeds with glycine betaine seem to improve photosynthetic pigments, osmo-protectants of vegetative organs, so enhancing sunflower salt tolerance and improving plant growth (so yield quantity and quality) [70].



## 26 Sweet potato

Latin name:	<i>Ipomoea batatas</i> (L.) Lam.
Vernacular names:	Sweet potato
Kind of stress	Humidity/Drought
Sensitivity	Sensitive, Moderately tolerant respectively
FAO-Threshold value (EC, dS/m)	1.5
FAO % Yield decrease (slope, % per dS/m)	11
FAO rating	MS
Area (ha):	21.203,50
Use:	food crops
Importance for Mekong Delta:	+
current economic value in mekong delta	Medium
Future potential for Mekong Delta:	High

### Current tillage:

In the Mekong Delta, sweet potato can be grown all year round. Most of the popular sweet potato varieties are local and some of them are imported from overseas. Japanese sweet potato varieties such as Hong and Purple have good productivity and quality in accordance with the Mekong Delta. The most suitable planting time for potatoes is late September to early October [71]. The sweet potato crop, once established, requires little field management apart from weed control. Sweet potato is adaptable to a wide range of climatic conditions from the warm humid tropics to mild sub-temperate zones from near sea level to 2000 m elevation. It has tolerance to low temperature in the higher altitudes, but is frost-sensitive.

### Management practices:

Potato fields are irrigated by sprinkler or drip irrigation.

In uplands, potato may be cultivated in cropping systems with other spring and summer crops such as corn, mung bean, soybean, sweet potatoes, vegetables [71].

Weeds are reduced to a minimum by a combination of hand-weeding, inter-row cultivation and the application of Paraquat (100 g ai/ha) over the crop. According to Lewthwaite and Triggs (2000) the herbicide Acetochlor shows a good control of the weed population without affecting sweet potato yield or quality, however Paraquat causes damage to sweet potato plants, although it effectively controls some weed species while other species, such as fathen, are not controlled [72].

### Recommendations:

It grows best on sandy loams that are well-drained and fertile, it is intolerant of waterlogging and is usually grown on mounds or ridges. It can be grown in semi-arid conditions, instead clayey soils can affect the yield. Soils below a pH of 4.5 are at a risk of aluminium toxicity, which severely reduces the growth and development of sweet potato [73].



## 27 Tomato

Latin name:	<i>Solanum lycopersicum</i> L.
Vernacular names:	Tomato
Kind of stress	Humidity/Acidity
Sensitivity	Sensitive
FAO-Threshold value (EC, dS/m)	2.5
FAO % Yield decrease (slope, % per dS/m)	9.9
FAO rating	MS
Area (ha):	-
Use:	Vegetables
Importance for Mekong Delta:	+
Current economic value in Mekong delta	Low
Future potential for Mekong Delta:	Medium

### Current tillage:

Tomatoes can be direct-seeded (500-1000 g seeds/ha) or transplanted in the field (70-90 g seeds/250 m<sup>2</sup> seedbed, enough for one ha). After transplanting, plants are spaced at 30-60 cm apart in single rows on 1.0-1.4 m wide beds, but sometimes a double-row bed system is used. Fresh-market tomatoes are often harvested at the mature-green stage and ripened in transit or in storage before they are marketed. However, tomatoes meant for further processing, are picked fully ripe. Tomato requires a relatively cool, dry climate for high yield and premium quality. However, it is adapted to a wide range of climatic conditions [74].

### Management practices:

Young seedlings need sufficient water, but a week before transplanting it should be reduced to harden them. Three/four-week-old seedlings (15-25 cm high with 3-5 true leaves) are ready for transplanting, then, they must be watered for 12-14 hours before they are lifted out of the seedbed. Tomatoes need appropriate irrigation during the early plant growth, fruit set and fruit enlargement stages.

For weed control, a pre-emergence herbicide may be applied onto the field beds before transplanting, including manual weeding and mulching the beds with rice straw. Crop rotation (lucerne and maize, for example) is a good way to reduce problems related to weeds by changing the environmental conditions. Moreover, a mound of soil (5-10 cm) put over the seed line at planting can reduce the first flush of weeds competing with the crop seedlings [74].

### Recommendations:

Tomatoes can be grown in many soil types (from sandy loam to clay-loam soils rich in organic matter). The ideal soil pH range is 6.0-6.5; a value outside this range can cause mineral deficiencies or toxicities. Long periods of flooding damage tomato growth and development [74]. Three cultural techniques seems to be partly useful in tomato overcoming the effects of salinity: treatment of seedlings with drought or NaCl, which improves the adaptation to salinity in adult plants; mist applied to tomato plants grown in Mediterranean conditions ameliorates vegetative growth and yield in saline conditions; grafting tomato cultivars onto right rootstocks [75].



## 28 Watermelon

Latin name:	<i>Citrullus lanatus</i> (Thunb.) Matsum & Nakai
Vernacular names:	Watermelon
Kind of stress	Humidity/Acidity
Sensitivity	Sensitive
FAO-Threshold value (EC, dS/m)	-
FAO % Yield decrease (slope, % per dS/m)	-
FAO rating	MS
Area (ha):	-
Use:	vegetables
Importance for Mekong Delta:	+
Current economic value in Mekong delta:	Medium
Future potential for Mekong Delta:	High

### Current tillage:

Watermelon seeds germinate under warm conditions within 5 days at optimal soil temperatures (21-35°C) but generally optimal soil temperatures are 18-28°C. Field crops are direct sown (1-2 kg seeds/ha) if soil is warm enough for germination, or transplanted when they have three-four true leaves, after 3-5 weeks (1.4-1.8 kg seeds/10000 transplants). Watermelon transplants are planted in single rows, 1.5-2.4 m apart, with 28-90 cm between plants in the row. The soil is tilled before planting and the pH adjusted to 5.8-6.6. Sometimes plastic mulches are used to help warm the soil early in the season, to conserve moisture and suppress weeds. Soils for cropping systems should be well-drained, light and fumigated before use to eliminate diseases caused by previous watermelon crops [76].

### Management practices:

Chemical weed control is the most widely used method; however, many growers use plastic mulch to eliminate the majority of weed species (apart from nutsedge). Hand weeding is performed too, then mechanical cultivation can be carried out before the crop starts to 'run' (vine).

Sprinkler and drip irrigation are the most common methods of irrigation and fertilizer can be put in the irrigation water. Sprinkler irrigation systems comprise centre pivots, linear move and travelling, permanent set and portable pipe with sprinklers. Drip irrigation can be used with or without plastic mulch and has the advantage of more efficient water use [76].

### Recommendations:

Watermelon is quite drought resistant and grows in hot, dry environments with high radiation levels. Fertile, sandy, well drained, loamy soil is preferred for cultivation (lighter soils warm quickly in spring and can give a higher early yield). Watermelon is moderately salt tolerant [76].



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## 29 Yam

Latin name:	<i>Dioscorea alata</i> L.
Vernacular names:	Yam
Kind of stress	Acidity
Sensitivity	Tolerant
FAO-Threshold value (EC, dS/m)	n.a.
FAO % Yield decrease (slope, % per dS/m)	n.a.
FAO rating	-
Area (ha):	-
Use:	Food crops
Importance for Mekong Delta:	+
Current economic value in Mekong delta	Low
Future potential for Mekong Delta:	Medium

### Current tillage:

Propagation is usually by cuttings of tuber, with each cut containing at least 2-3 dormant buds; then, tuber is left in the sun for several hours to encourage wound healing and reduce the risk of fungal infection [77].

Tuber dormancy lasts for 2-4 months after harvest; the small intact ones ('seed tubers') or tuber pieces weighing 50-500 g are used for planting on mounds, ridges, or on the flat. Plants are usually staked soon after emergence. Harvesting occurs 7-10 months after planting. Yields range from 8-30 t/ha. Individual tubers usually weigh 5-10 kg [78].

### Management practices:

In sole cropping system, rows are 1 m apart, and the intra-row spacing is approximately 50-100 cm. In general, yam is the first crop in the rotation after fallow; anyway, intercropping is the most common practice.

Weeding is done 3-4 times during the season.

Most production in South-East Asia takes place without irrigation, mechanization or even chemical fertilizer [78].

### Recommendations:

Yam thrives best in deep, well-drained, sandy loam soils, but also performs in medium to clay loams' ones. The preferred range of pH is between 5.5 - 6.5. Daylengths of more than 12 hours are preferred during the early growing season to encourage vegetative growth, while, towards the end of the growing season, daylengths of less than 12 hours promote tuber development [77].

Yam grows in areas with mild temperatures (around 15-35°C) and high precipitation (>1000 mm annual rainfall), at low to middle elevations. It is partially adapted to shaded conditions, but does not tolerate frost [78].

## 30 New crops

### 30.1 Quinoa

Latin name:	<i>Chenopodium quinoa</i> Willd
Vernacular names:	Quinoa
Kind of stress	Salinity/drought
Sensitivity	Extremely tolerant
FAO-Threshold value (EC, dS/m)	20
FAO % Yield decrease (slope, % per dS/m)	5
FAO rating	Highly tolerant
Area (ha):	-
Use:	Food crop
Importance for Mekong Delta:	?
Current economic value in Mekong delta	none
Future potential for Mekong Delta:	Possibly high

#### Current tillage:

Quinoa (*Chenopodium quinoa* Willd.,  $2n = 4x = 36$ ) is a highly nutritious crop that is naturally adapted to thrive in a wide range of agroecosystems. Quinoa originate from South America and has adapted to the arid and saline soils of the high plains of the Andean Altiplano. Quinoa is not particularly heat tolerant. Long periods  $> 35$  °C reduce grain yield. Yield levels range from 400 to 4,000 kg/ha depending on climate, soil and management practices. Quinoa can reach its potential yield with only 300 mm of water. Global acreage is  $> 170,000$  ha and increasing to satisfy a fast-growing demand.

#### Management practices:

Quinoa can be sown with soil temperatures above 5 to 10 °C. At an expected grain yield of 2,000-3,000 kg/ha, about 150 kg N/ha is needed and P and K fertilization similar to spring cereals. Quinoa is sown at a seeding rate of 10 kg/ha. Row distances between 10 and 50 cm have been used. At 50 cm, mechanical weeding is possible, but generally a 15 cm row distance is used. Grass herbicides can be used against grassy weeds (if allowed). Weed control should be carried out before germination of quinoa using false seed bed preparation and/or herbicides as most herbicides against broad-leaved weeds will also kill quinoa. Aphids and Lygus bugs may attack the crop and caterpillar damage has occurred in some countries. Downy mildew (*Peronospora farinosa f.sp. chenopodii*) resistant/tolerant varieties should be used (some new non-bitter varieties with a good level of mildew resistance are available). Harvesting and threshing can be carried out manually, but mechanical harvesting with combine harvesters is used often.

#### Recommendations:

Quinoa is recommended to be used on saline soils with salinity levels up to E<sub>c</sub> of 40 dS/m when the water use by the crop (about 300 mm) is replaced by natural rainfall to avoid increasing the EC due to the water use of the crop. Saline irrigation water of an EC up to 20 dS/m can be used but care should be taken to avoid accumulation of the salt from irrigation water or to drain the soil to move any accumulated salt to deep layers. Varieties should be used that do not produce bitter saponins in the outer seed (fruit) layer as otherwise high costs for saponin removal are incurred.

<https://hort.purdue.edu/newcrop/afcm/quinoa.html>

<https://www.wur.nl/en/newsarticle/Award-for-Quinoa-project.htm>



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# Annex 1 Overview of the crops, proposed to the project team for an expert judgement

	Crop	Scientific name	Importance for Mekong $\Delta$	Kind of stresses	Classification	Area	Current Economic value in Mekong $\Delta$	Future potential for Mekong $\Delta$
Tropical Fruits	Ambarella	Spondias dulcis	+	Drought	M	N/A	L	L
Tropical Fruits	Bacaurea	Baccaurea ramiflora	+	Drought	M	N/A	L	L
Tropical Fruits	Banana	Musa	+	Drought/Salinity	M	39,492	M	H
Vegetables	Beans	Phaseolus	-	Drought/Salinity	S	9,172.40	L	L
Vegetables	Bitter	Momordica charantia	-	?				
Extra mentioned	Black bean	Phaseolus		?		350.9		
industrial crops	Black pepper	Piper nigrum	-	Acidity/Salinity	S	885.1	L	M
Vegetables	Cabbage	Brassica oleracea	-	Drought/Salinity	S	N/A	L	L
Extra mentioned	Cashewnut	Anacardium occidentale		?		1,700		
Tropical Fruits	Cerise	Malpighia glabra	+	Drought	M	N/A	L	L
Vegetables	Chilli	Capsicum annuum	-	Humidity/acidity	S	N/A	L	M
industrial crops	Cocoa	Theobroma cacao	+	Acidity/Salinity/drought	S/S/M	4000	L	M
industrial crops	Coconut	Coco nucifera	+	Salinity	T	141,615	M	H
food crops	Corn, maize	Zea mays	+	Humidity	S	38,230	M	H
Vegetables	Cucumber	Cucumis sativus	+	Drought/Salinity	S	N/A	M	M
Tropical Fruits	Dragon fruit	Hylocereus undatus	++	Drought/Acidity	M	12,115.70	M	H
Vegetables	Garlic	Allium sativum	-	Humidity	S	N/A	L	M

Extra mentioned	Green bean	Phaseolus		?		7,758.60		
industrial crops	Groundnut	Arachis hypogaea	+	Humidity/Drought	M/S	13,021	M	H
Tropical Fruits	Guava	Psidium guajava	+	Drought/Acidity	M	N/A	L	M
Tropical Fruits	Jack fruit	Artocarpus heterophyllus	+	Drought	M	N/A	L	M
Vegetables	Japanese parsley	Oenanthe javanica	-	Drought	S	N/A	L	M
industrial crops	Jute	Corchorus olitorus	-	Acidity/Salinity	T/M	35.7	L	L
Vegetables	Keo neo	Limnocharis flava	-	Acidity	M	N/A	L	M
Tropical Fruits	Lemon	Citrus limon	+	Drought/Acidity	M	N/A	L	M
Vegetables	Lettuce	Lactuca sativa	-	Drought/salinity	S	N/A	L	L
Tropical Fruits	Longan	Dimocarpus longan	++	Drought/salinity	M	28,350	M	H
Tropical Fruits	Lotus	Nelumbo nucifera	+	Humidity/Acidity	T	N/A	L	M
Tropical Fruits	Mandarins	Citrus reticulata	+	Humidity	S	6,669	M	H
Tropical Fruits	Mango	Mangifera indica	++	Drought/salinity	M	38,773	H	H
Tropical Fruits	Mangosteen	Garcinia mangostana	+	Drought/Salinity	M	N/A	L	M
Vegetables	Morning glory	Ipomoea aquatica	+	humidity/Salinity	T/M	N/A	M	M
Extra mentioned	mulberry	Moraceae		?		1.1		
industrial crops	Mungbean	Vigna radiata	+	Drought/Salinity	M/S	7,758.60	L	M
Tropical Fruits	Orange	Citrus sinensis	+	Humidity/Salinity	S/M	32,939.20	M	H
Tropical Fruits	Papaya	Carica papaya	+	Drought/Salinity	M/M	N/A	L	M
Extra mentioned	Peanut	Arachis hypogaea		?		13,021.20		
Tropical Fruits	Pineapple	Ananas comosus	++	Drought/Acidity	T	25,370	M	H
Tropical Fruits	Pomelo	Citrus maxima	++	Drought/Salinity	M	25,173	H	H
Tropical Fruits	Rambutan	Nephelium lappaceum	+	Drought/salinity	M	9,965.60	M	M
food crops	Rice	Oryza sativa	+	Drought/Salinity	S,M	4,308,644	H	H
Tropical Fruits	Sapote	Manilkara zapota	+	Drought	M	N/A	L	M
Extra mentioned	Sedge	Cyperaceae				5,582.70		
industrial crops	Sesame	Sesamum indicum	+	Drought/salinity	M	24,451.60	M	H
Vegetables	Shallot	Allium cepa var. aggregatum	+	Acidity	M	N/A	L	M

Tropical Fruits	Soursop	Annona muricata	+	Acidity/Salinity	T	N/A	L	M
industrial crops	Soybean	Glycine max	+	Drought/salinity	M	1,147.20	L	M
Vegetables	Squash	Cucurbita pepo	-	Humidity	S	N/A	L	L
Tropical Fruits	Star apple	Chrysophyllum cainino	+	Drought	M	N/A	L	M
industrial crops	Sugarcane	Saccharum officinarum	+	Acidity/Salinity/drought	M	50,348.70	M	H
industrial crops	Sunflower	Helianthus annuus	-	Drought	M	N/A	L	L
food crops	Sweet potato	Ipomoea batatas	+	Humidity/Drought	S/M	21,203.50	M	H
Extra mentioned	Tabaco	Nicotiana				28		
Vegetables	Tomato	Solanum lycopersicum	+	Humidity/acidity	S	N/A	L	M
Extra mentioned	Vegetables			?		253,160.20		
Vegetables	Watermelon	Citrullus lanatus	+	Humidity/acidity	S	N/A	M	H
food crops	Yam	Dioscorea alata	+	Acidity	T	N/A	L	M

## Annex 2 Overview of the selected crops

Crop	Use	Important for Mekong Δ	Kind of stresses	Rating	Area	Area mentioned by Hien	Current Economic value in Mekong Δ	Future potential for Mekong Δ	FAO-rating		
									Treshold	Slope	Classification
Beans	Vegetables	-	D/S	S	N/A	9,172.40	L	L	1	19	S
Cabbage	Vegetables	-	D/S	S	N/A		L	L	1.8	9.7	MS
Coconut	industrial crops	+	S	T	141,615		M	H			MT
Corn, maize	food crops	+	H	S	38,230	38,000	M	H	1.8	12	MS
Dragon fruit	Tropical Fruits	++	D/A	M	12,115.70		M	H			
Groundnut	Industrial crops	+	H/D	M/S	13,021		M	H	3.2	29	MS
Jack fruit	Tropical Fruits	+	D	M	N/A		L	M			
Longan	Tropical Fruits	++	D/S	M	28,350	30,754.30	M	H			
Lotus	Tropical Fruits	+	H/A	T	N/A		L	M			
Mango	Tropical Fruits	++	D/S	M	38,773	38,773.20	H	H			S
Mangosteen	Tropical Fruits	+	D/S	M	N/A		L	M			
Mungbean	industrial crops	+	D/S	M/S	7,758.60		L	M	1.8	20.7	S
Orange	Tropical Fruits	+	H/S	S/M	32,939.20	32,133.90	M	H	1.3	13.1	S
Papaya	Tropical Fruits	+	D/S	M/M	N/A		L	M			MS
Pineapple	Tropical Fruits	++	D/A	T	25,370	25,370.20	M	H			MS
Pomelo	Tropical Fruits	++	D/S	M	25,173		H	H			
Rice	food crops	+	D/S	S,M	4,308,644	4,308,644	H	H	3	12	S

Sesame	industrial crops	+	D/S	M	24,451.60	24,451.00	M	H			
Shallot	Vegetables	+	A	M	N/A		L	M			
Soursop	Tropical Fruits	+	A/S	T	N/A		L	M			
Soybean	industrial crops	+	D/S	M	1,147.20	1,147.20	L	M	5	20	MT
Sugarcane	industrial crops	+	A/S/D	M	50,348.70	50,348.70	M	H	7	5.9	T
Sunflower	industrial crops	-	D	M	N/A		L	L	4.8	5	MT
Sweet potato	food crops	+	H/D	S/M	21,203.50	21,203.50	M	H	1.5	11	MS
Tomato	Vegetables	+	H/A	S	N/A		L	M	2.5	9.9	MS
Watermelon	Vegetables	+	H/A	S	N/A		M	H			MS
Yam	food crops	+	A	T	N/A		L	M			

#### Legend

Kind of stresses	A	Acidity
	D	Drought
	H	Humidity
	S	Salinity
Rating	T	Tolerant
	M	Moderately tolerant
	S	Sensitive
Economic value	L	Low
	M	Medium
	H	High
Area	N/A	Not available data
	-	Not quantitative data







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