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**Faculty of Landscape Architecture, Horticulture and Crop Production Science**

# Agroecological analysis of Maldivian agricultural system to improve nutrient management

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**Agroecological analysis of Maldivian agricultural system to improve nutrient management**

Agroekologisk analys av Maldivernas jordbrukssystem för att förbättra näringsämnen

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LIST OF ACRONYMS

| | |
|---|---|
| ADB | Asian Development Bank |
| ADMP | Agriculture Development Master Plan |
| CPF | Country Programming Framework |
| FAO | Food and Agriculture Organization of the United Nations |
| GDP | Gross Domestic Product |
| GEF | Global Environmental Facility |
| MoFA | Ministry of Fisheries and Agriculture Maldives |
| SAFA | Sustainability Assessment for Food and Agriculture Systems |
| UNDP | United Nations Developmental Program |

## Foreword

Maldives is unique in many ways than most countries are not. It lacks much resources to sustain agriculture the way depicted in many parts of the world. Following other countries as a template would be much to our detriment than success, for farmers are still struggling with issues they expected to have been solved when they took up conventional practices. I have sometimes wondered why farming based on traditional and ecological ideas have become such confusing and alien concept for the new generation of farmers. I assume in some ways the influx of new technologies, ready-made seeds, fertilizers and pesticides might have something to do with it. Perhaps, we ought to not create 'silver bullets' where it is not needed. A six-year intense agricultural education may not be necessary to acknowledge what must be done to improve Maldivian agriculture sector. It has been obvious to me for a while. But education help to set a stronger tone when changes are to be proposed. This is the main reason why I came to Sweden. The Agroecology program has expanded my understanding and helped to strengthen my convictions. Few months in to the program I begin to realize, integration of environmental aspects in to the production system is not merely an option but the only way forward and we must be quick about it. If there is any production system that need prioritizing environmental angle before setting production practices, (however un realistic this may seem) is the Maldives. Since my naivete need to address everything at once is strong and my interests concerning Maldivian agriculture sector are many, system analysis seems the only way to go about exploring the issues. I tried to employ methods that can generate a comprehensive understanding. In this respect, the concept of 'methodological pluralism' discussed in agroecosystem analysis literature was adopted throughout. I hope this study sheds some light in bringing the much needed changes to Maldivian agriculture sector.

# Abstract

An agroecological analysis with focus on nutrient management was carried out for the farming systems of Northern Maldives using 'Peanut model'- agroecosystem analysis framework described by Bawden et al (1986). Even though much of the practices are similar throughout the country, the focus of the study was on the farming activities of inhabited islands in northern region. The main objective of the study was to carry out a system analysis to identify major agriculture practices with relation to nutrient management. Analyses were based on in-depth observations carried out at three case-study farms from three inhabited islands (Komandoo, Nolhivaram and Kaashidhoo) in the north. Additionally, 30 farmers from the region were interviewed using semi-structured interviews. Apart from that data was collected through group discussions, transect walks, stakeholder interviews, basic soil analysis and SAFA assessments were carried out at the case-study farm islands. Many poor practices were identified as part of the routine nutrient management operations such as fertilizer mixing, routine field burning, low nutrient recycling and heavy dependency on external inputs. Lack of knowledge on general agricultural practices, average age of farmers, poor focus on agri-sectoral development are some of the reasons identified in this study.

# 1. Introduction

Agriculture has been an important aspect of livelihood for Maldives for generations. However, the importance of agriculture in the country has been underestimated because of its low contribution to the GDP. In 2015, tourism sector contribution to GDP was 30% while agriculture sector that of agriculture sector as <5% (Food and Agriculture Organization of the United Nations, 2018). Furthermore, the impact of climate change on the low-lying archipelago and the devastation caused by natural disasters such as December 26, 2004 tsunami, represent further risks to the progress of the sector (Country Program Framework for Maldives, 2018). Nonetheless, agriculture is important for food security of the country in two ways; it provides food for households' consumption, and perhaps more importantly, it is an income generating activity for a large portion of the country (Ministry of Fisheries and Agriculture, 2009). Moreover, agricultural activities in both inhabited and uninhabited islands take relatively large portion of the country's' natural resources such as land and ground water usage.

Currently Maldivian production systems can be labeled as 'conventional' primarily for the predominant presence of agrochemical use and heavy dependency on external inputs (MoFA, 2009). Use of synthetic fertilizer in Maldivian islands were not recorded until late 1980's (World Bank, 1980). The term 'small farm' is relative in Maldivian context where average commercial farm size is less than 0.1ha and farms with one hectare or more are rare in inhabited islands. FAO estimates that nitrogen fertilizer consumption in Maldives has increased from less than 70 tonnes in 2005 to 770 tonnes in 2014 (FAO, 2018). Interestingly, the total cropped area in the country during this time has remained quite the same at about 2900 – 3000ha (FAO, 2018). Maldivian ecosystem is fragile and nutrient leaching, especially for nitrogen is quite well known, and the problem is further magnified in shallow, sandy and well-drained soils (Herzong and Konrad 1992). Managing fertilizer inputs in a judicial manner is not just important for ecosystem but also for resilient farm management.

Agroecological analysis is about identification of major contributing factors at a system level and explore possibilities for agroecological improvement by finding ways to fine-tune production practices in the direction of sustainability. This process is described by Gliessman et al (2007), as the levels or steps for achieving agroecological design in any farming system. There has not been a system level study on the agricultural system conducted in the Maldives. After a thorough search no published journal article was found on Maldivian agriculture. An overview of the agriculture system with a specific focus on nutrient management seems to be a good starting point, as it is an important and key aspect in production system. Therefore, this exploratory study aims to understand the nutrient management in Maldivian agricultural system using agroecological system analysis approach in the Northern region of the country.

# 2. Background Information

## 2.1 Status of agriculture sector

Maldives is identified as one of the growing economy in Asia. It has the highest Human Development Index (HDI) ranking in South Asia: 95 out of 182 countries (UNICEF, 2015). In addition, Maldives has achieved five of the eight Millennium Development Goals ahead of schedule, making it South Asia's only "MDG+" country (UNICEF, 2015). Agriculture sector employs 8000 registered farmers and the sector contributes <5% to national GDP (MoFA, 2018). The agricultural practices have deviated from traditional practices from low external inputs to high external input dependent system as the booming of tourism sector in 1980's brought about better shipping and trade connections (Guillaumont, 2018). Being a small country, the large service industry created by tourism sector required continuous importation of large amount of food, most of which are not technically feasible to be produced in the country due to land and geographical limitations (FAO, 2018). The trade connections made during this time to acquire food and other resources made it also possible for the commercialization of agriculture. In an effort to promote this mandate, importers are allowed 30% discount on import duties for any agricultural related inputs through import regulation (Guillaumont, 2018).

Agricultural production system in the country can be broadly grouped into three categories;

- Firstly, as home-garden production in homestead or land assigned for residential needs.
- Secondly, in communal plots in inhabited islands leased for farming according to the regulations of the respective island councils – on monthly, yearly or seasonal basis with or without tenure.
- Thirdly, as farming activities carried out on uninhabited islands that are rented for a 5 to 21year lease.

There are 32 uninhabited islands assigned for agricultural production as of 2015 (MoFA, 2018). The total area of these islands varies from 5-40ha. These islands are operated by established entrepreneurs which have either local or foreign ownership, and the production stability in terms of yield performance can vary, with some islands doing significantly poor than the others. FAO estimates the total arable land area of the country at around 2,800-3000ha (Figure 1). Agriculture in inhabited islands consists about two-thirds (1800-2000ha) of this. However, according to MoFA this total estimate may not account for the area under homestead production (MoFA, 2009). Homestead production at inhabited islands is mainly concerned with growing perennial crops and is generally less intensive (Building capacity and mainstreaming sustainable land management in the Maldives, 2013). Agriculture is more prominent in the islands of Central and Northern region compared to South (MoFA, 2018). In the 200 inhabited islands, 128 have a population less than 1,000 (CPF, 2018).

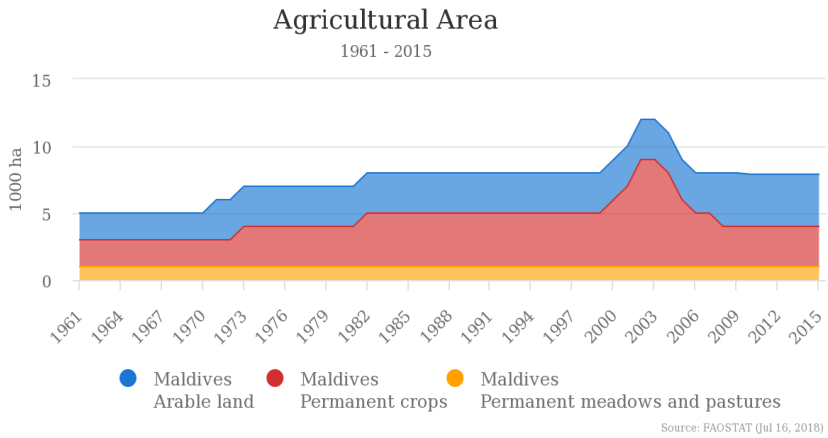


Figure 1: Agricultural area 1961-2015. Includes estimates of FAO and Maldives National Planning. Source:(FAO, 2018).

## 2.2 Farming in historical times

Historically, agriculture has been the major livelihood activity in the inhabited islands along with fishing until 1980's. Land allocation for farming during those days were carried out based on community understanding without much intervention of authorities. The harvest were used for home consumption and for bartering. Land preparation was carried manually by clearing natural vegetation and burning the dried vegetation. Ash is then spread with a wooden rake, but deep tilling was not practiced. There was little or no use for additional tools and implements, inorganic or organic fertilizer, or pesticides. When a plot is deemed unproductive it is left as fallow and a new area is cleared for production. Fallow for one to two years was quite common (Liebregts, 2007). However, mixing ash and dry leaves with soil during planting to extend cultivation period was also practiced in some islands. Additionally, fish offal, bones and other remains from fish processing and decomposing coconut wood had been incorporated directly to soil before planting.

Seasonal preference for growing is given for specific crops, finger millet (*Eleusine coracana*) and italian millet (*Setaria Italica*) and maize (*Zea mays*) were grown widely throughout the Maldives during the southwest monsoon (May-Oct). Sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*), and yams were grown in the southern islands. Bread fruit *(Artocapus altilis*) and coconut plants (*Cocos nucifera*) were the other main carbohydrate crops that were present in the islands as part of domestic and natural vegetation. Farmers used local crop varieties of chili (*Capsicum spp*), brinjal/eggplant (*Solanum Melongena*), capsicum (Capsicum spp), watermelon (*Citrullus lanatus*), pumpkin *(Cucurbita pepo*), banana (*Musa spp*) and papaya (*Carica papaya*) (Liebregts, 2007). These varieties were hardy and improved through open pollination in the island environments. Feral and domesticated chicken and ducks were prevalent in homesteads. They were mostly loose and allowed to roam free in the islands. Though deliberate use of chicken manure as nutrients was not common, it helped to improve species diversity for the ecological system and some form of pest control for insect pests.

The islanders relied mostly on locally produced products except for occasional consignment of

rice, wheat, sugar and spices. These products did not become as staple food until the mechanization of sea vessels and expansion of shipping industry with subsidization of these three commodities (Liebregts, 2007).

## 2.3 Agriculture in current times

Presently, agricultural production is predominantly focused on horticultural crops. Vegetables and tropical fruits including watermelon, papaya and banana are dominant. There are no cereal grain crops and nuts grown, except for coconut and tropical almonds. Betel leaves *(Piper betle*), chili, local-kale and watermelon are some of the most important cash crops (Liebregts et al, 2005). The crops fall under narrow group of plant families. They are also mostly imported hybrid varieties. Livestock is also rarely raised except for a few poultry and cattle ventures (MoFA, 2018). Poultry without caged or fenced settings in inhabited areas are currently prohibited by law. With intensification and commercialization of agriculture, irrigation is now commonly used. In some islands such as Thoddoo, have become specialized for production of watermelon. Crops such as bananas, papaya, taro, sweet potatoes, chili and leaf cabbage are grown at farms throughout the year (MoFA, 2018). Pressure on communal cropping land increased with shortened fallow periods. Consequently, the use of synthetic fertilizers is on the rise (Figure 2). Pesticide consumption has also increased on many islands. Although there is regulation for importing agrochemicals; currently, comprehensive government policy covering the use of fertilizers and pesticides is lacking (MoFA, 2018). Instructions are given to buyers on the usage of fertilizers and pesticides, however their use is largely uncontrolled.

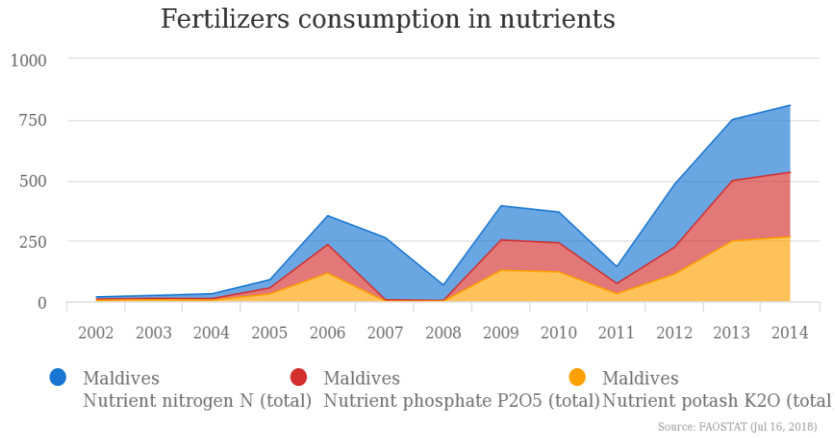


Figure 2: Fertilizer consumption in nutrient 2002-2014. Includes estimates of FAO and Maldives National Planning. Source: (FAO, 2018).

Apart from these, various types of conventional hydroponic systems have been widely adopted for growing leafy vegetables such as lettuce (*Lactuca sativa*) and kungkang (*Ipomoea aquatica*) and high-value crops like cucumber (*Cucumis sativus*) and sweet melon (*Cucumis melo*). The hydroponics production systems have been heavily promoted by MoFA since 2001(MoFA, 2009). These systems are based on conventional imported hydroponics nutrient mixtures.

Government extension services has the mandate to advise farmers in all 200 islands in various aspects of farming. However, due to the low financial capacity and lack of skilled human resource, the advisory packages are condensed and short-term based usually for period of 7-14 days. All

programs are based on 5 major areas, namely: general agricultural practices, hydroponics, home gardening, pest and disease management and agri-business management. The training and extension unit has roughly 20 permanent staff and out of that only 7 people are involved in active information dissemination.

# 3. Aim and objectives

There is significant knowledge gap on existing agricultural practices of the islands. The main aim of this study therefore, was to assess the current farming practices by the Maldivian farmers, with focus on nutrient management in the production system. The following three specific objectives were set out to address the research objective:

- To analyze the aspect of nutrient management in Maldivian farming system through an agroecological analysis based on agroecosystem analysis framework.
- To identify and evaluate existing nutrient management practices in the general farmer community through case-study farms and interviews.
- To identify and recommend suggestions to the farming system in general, with regard to nutrient management using Gliessmans scale on agroecosystem change.

# 4. System boundary

Homestead farming has been practiced in all inhabited islands in Maldives since times immemorial which aids to households' nutritional needs in terms of providing fresh fruits and vegetables. Cultivation in homesteads is a year-round activity. There are no major differences between islands on how farming is practiced and since farming in small areas encompass the mass of farmer and community involvement, this thesis focuses on the farming activities in inhabited islands namely; homestead production and farming activities in leased plots by island councils. More specifically the 'system' hereafter in the thesis refer to farming activities of inhabited islands in the central-north and northern region of Maldives.

# 5. Materials and methods

This thesis work was carried out in collaboration with the research and extension services of the Ministry of Fisheries and Agriculture, Maldives. The system analysis is carried out based on Hawkbury's peanut model for agroecosystem analysis. This framework was developed by Bawden et al (1984) as a full-scale concept that take into account the ecological, social, cultural and economic aspects of agroecosystem (Figure 3). It takes farming as human induced activity on natural system that is coevolving with its environment towards an improved state. This framework seems most relevant in getting a holistic view of the system while at the same time being able to study a specific defining component of it such as nutrient management.

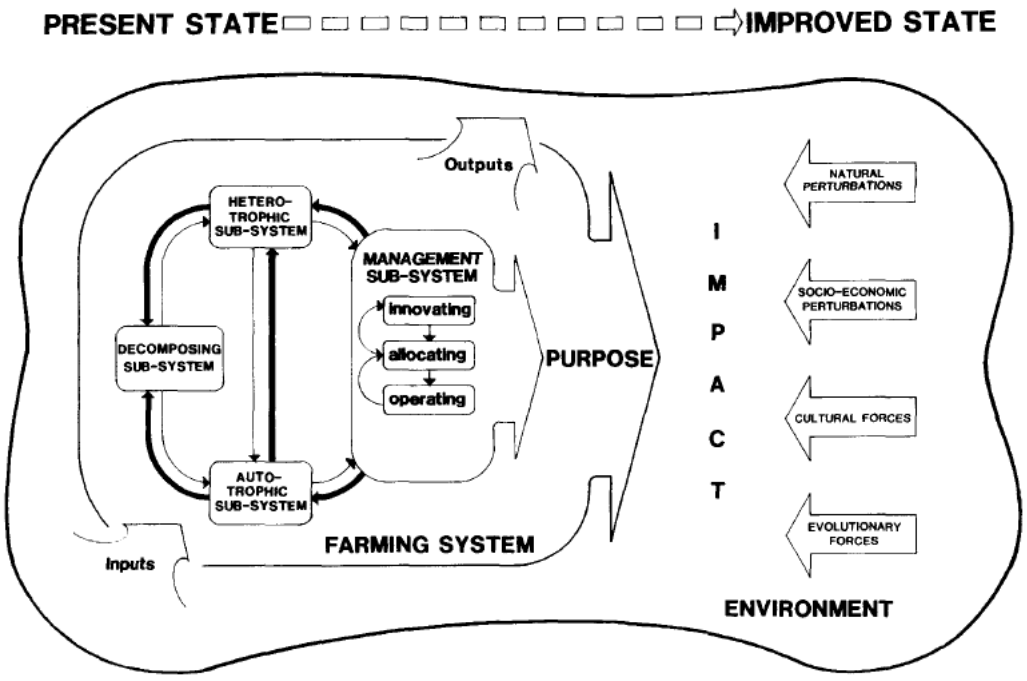


Figure 3: Hawekesbury's Peanut Model - A comprehensive tool for agroecosystem analysis. Source: Bawden et al 1984.

Brief literature review was carried for information pertaining to historical and existing farm management practices. Relevant information was analyzed from government publications and reports from international organizations. Since published data is limited, additional important information were obtained from the unpublished archives of Ministry of Fisheries and Agriculture. This include, background information of the case study farm islands as well. Theoretical basis for system analysis was based on work done by Gliessman (2007), Altieri (2012) and Francis et al (2003) on the concept of agroecology, system thinking and frameworks in adopting agroecological change in small holder farming systems. The farm is considered as a complex entity and the focus was given on activities around nutrient management. The 'critical realist' approach, which combines a general philosophy of science (transcendental realism) with a philosophy of social science (critical naturalism) to describe an interface between the natural and social worlds (Woodside, 2010) is used in the analysis of the farming systems in this study. In addition, key ideas are taken from Francis et al (2003) on addressing open-ended cases in agroecology.

## 5.1 Case-study farms and locations

This thesis focuses on farming in central and northern region of the country (See Figure 4 below). Although, farming is prevalent in all islands, in current times, these regions account for majority of the agricultural production in the country. Three case-study farms are based in Hdh.Nolhivaram and K.Kaashidhoo and in the uninhabited island of Sh.Mathikomandoo which is managed by the island council of nearby Sh.Komandoo. In addition to the general farming practices in the island, specific attention to nutrient management practices was evaluated. These case study farms were chosen based on their similarities to the farming system type as described under system boundary section of this thesis. Hence, the case-study farms were used to find a comprehensive understanding and better view on the similarities and differences between the case farms rather than as part of comparative analysis. Location of the studied islands and the various activities carried out in relation to collecting data for this thesis is shown in Figure 4. A total of six islands were visited for interviews and data collection. In terms of length, the North central and Northern region encompass close to half of the country.

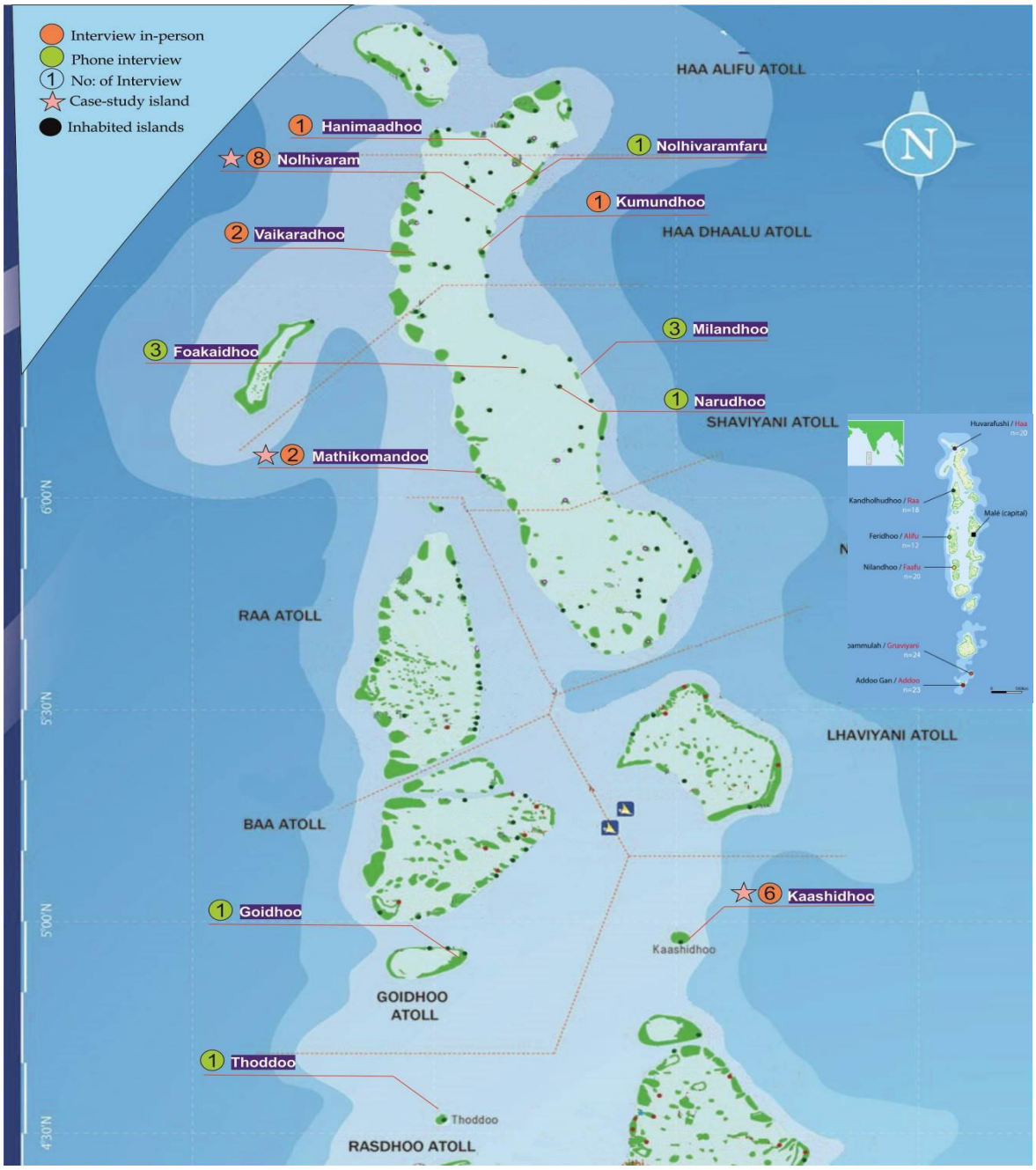


Figure 4: Map of the Central-north and Northern region with marked location and activities carried out for the study. Image: [www.themapofmaldives.com](http://www.themapofmaldives.com) (cc)

## 5.2 Semi-structured interviews

Information on the current farming system was collected through semi-structured interviews with 30 farmers from the northern region using nonprobability convenience sampling method. This method seems appropriate since farmers from case-study islands and surrounding islands were

given priority for the interviews. The interview questions collected both quantitative and qualitative data using closed and open-ended questions with focus on existing nutrient management practices, knowledge on alternative farming practices and current approach in general farming methods. The questionnaire was tested with two respondents (a farmer and advisor) before carrying out the final interviews, and necessary changes were made accordingly. Most of the interviews were carried out in-person given the cost of travel and time. Some farmers are contacted a second time for additional information and clarification. The remaining interviews were made through phone conversations (see appendix 3 for interview guide).

Apart from that, five stakeholder interviews were carried out. This include an interview with a member of the island council from each case study islands, an advisory service officer and the director general for agriculture division at MoFA. The main aim of these interviews were to gain an understanding of the perspectives of other actors involved in agriculture sector. Most of the information was used for understanding various perturbations from political and social economic areas. Apart from that information was accumulated through these interviews relate to advisory services and existing regulatory issues at country and island level (see appendix 4 for stakeholder interview guide).

## 5.3 Focus group discussions

Apart from that, focused group discussions were carried out in two of the case study islands (Komandoo and Nolhivaram) (Figure 5b-c). There were 22 participants from Komandoo and 15 participants from Nolhivaram. In most sessions, after initial discussions, participants were placed in five to six member groups to identify main points in a flipchart and present to the other participants. The written flipcharts were later translated to English from Dhivehi for analysis. There were four sessions of 90-120 mins duration in both Komandoo and Nolhivaram island (see appendix 1 for group discussion guide). The sessions were arranged around important topics such as barriers to livestock use in farms, composting, differences in current and traditional nutrient management practices etc. The participants were mainly composed of farmers and island council members (see appendix 2 for brief synthesis of the discussions). In addition, an hour long session was carried with the secondary grade school students in these two Islands on their perspectives on agriculture as a career pathway and their view on farming practices carried out in their respective islands. On average there were 40 participants in each session aged between 13-16 years (Figure 5a).

Figure 5 (a)- Discussions with secondary grade school students of Komandoo (Source: This study)

Figure 5(b)-Group discussion with farmers and council member in Komandoo (Source: This study)

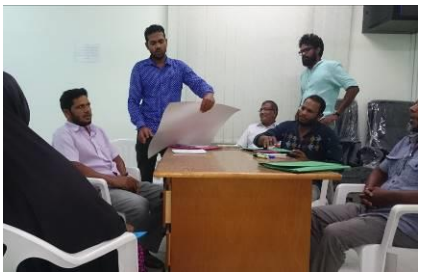

Figure 5(c)-Group discussion with farmers and council members in Nolhivaram (Source: This study)

## 5.4 Transect walks

Moreover, a transect walk was carried out at each case-study farm island. The main aim of this was to identify available and accessible nutrient sources for the farmers. This activity also helped in obtaining general understanding of the state of natural resources (vegetation, soil, water), socio-economic setting and identification of processes that are associated with land and management practices of each island. Hence, the main information acquired through this method was used in defining the system environment (soil, land management) as well as potential alternative nutrient management practices. This activity was carried out with the help of a guide appointed by the island councils (see Appendix 5).

## 5.5 Soil tests

Additional to observing farmers' practices in the farm, soil test for pH, Nitrogen, Phosphorus and Potassium were carried out using NICE Soil Testing Kit approved for field work by MoFA (Nicechemicals.com, 2018). It is a simple-to-operate kit which is designed to aid in nutrient management decisions. Tests were done in all three case-study farms. 10 soil samples were taken from 15 cm depth from 10-15 points of the plot in each farm and mixed well to get a representative sample.

## 5.6 Sustainability Assessment for Food and Agricultural Systems (SAFA)

Moreover, Sustainability Assessment of Food and Agriculture systems – SAFA small holder mobile app was used to carry out an overall sustainability assessment of the three case-study farms. The main objective of this was to get a general view on the sustainability direction of the farms based on the current practices. SAFA small holder app was developed and promoted by FAO and tailored for small agribusiness based on the SAFA model (SAFA small holder app, 2016). This application was a helpful tool which made the assessment simpler and concise. Hence, the

questionnaire in the SAFA tool is a narrowed down version encompassing all the themes of the four sustainability dimensions based on 100 focused questions.

# 6. Results

## 6.1 Environment

### *Sh.Komandoo*

Komandoo is a 10ha land situated 213km north west of Male'(the capital city of Maldives). It is the second most populated island in Shaviyani atoll with a population of 1600 people (Atollsofmaldives.gov.mv, 2018) (Figure 6). Due to the small land area and residential needs using up most of the space, there are no natural/wild areas left in the island. Main income comes from family members working in the tourism sector. during the last one or two decade, there have been huge land reclamation effort done along the perimeter for coastal protection and to create space for recreational and industrial use. There have also been work on new sewer system and since the groundwater is depleted, now only the central desalination facility provides water for all household needs.

The main farming activity is carried out in the form of homestead farming where backyards and lawn areas are used for producing vegetables and local fruits such as guava (*Psidium guajava*), mango (*Mangifera indica*), passion fruit (*Passiflora edulis*), waxapple and (*Syzygium samarangense*). Apart from this the island of Mathikomandoo- an uninhabited island two km north of Komandoo is leased by the island council for farming and fisheries activities (Figure 6). The island is nine ha in size and leased to around six farmers from Komandoo for farming activities. In this island, farming is done mostly on seasonal basis producing high value cash-crops such as watermelon, chili, local kale and brinjal. The farmers make routine trips in their small motor dinghy on daily basis. Each farmer has small sheds for storage in their designated plots. Although there is no electricity here the ground water is used for irrigation through bore wells.

Figure 6: Drone image of the inhabited island of Komandoo and farming island of Mathikomandoo (background). Image: Komandoo island council

## *Case-study farmer*

The farmer is a 29 year old fulltime employee at the local island court authority. He has spent his childhood and youth with his farther in farming in Mathikomandoo (Figure 7). Due to his fathers' poor health he has now taken in-charge of the activities. He is newly married with no children and although he does not fully depend on farming as a livelihood activity it has become a second source of income and a routine activity which he enjoys. He is considered a seasonal farmer in Maldives, producing mainly watermelon and chili for the month of Ramazan. Therefore, the cropping activity takes about four to six months a year including the preparation time. Since there are no fixed plot allocated to farmers in Mathikomandoo, plots are rotated and while allowing the most recently cropped land to stay under fallow for a year. This allocation of plot is done with the help of island council on yearly basis following an application filed by the farmers. Each farmer is allowed to manage two to three plots of 950 square meters each. There are no fees charged for land or use of any resources in the island. The whole operation is carried out under a loose code of conduct issued by the Komandoo island council. The code constitutes restriction on vegetation clearing, number of bore wells that can be drilled, and types of crops permitted for cultivation.


Figure 7: Case-study island of Mathikomandoo. Image: Komandoo island council.

## *H.dh Nolhivaram*

Contrast to Komandoo, Nolhivaram is a relatively bigger island in relation to other islands in the country (Atollsofmaldives.gov.mv, 2018). It is located 281km North of Male' in the atoll of Haadhaalu with a size of 203ha and a population of 2500 (Figure 8). The island is 15 minutes by speed boat from the nearby Hanimaadhoo international airport. It is also a 20 minutes' ferry ride from the atoll capital island of Kulhudhufushi - the main market for most of agricultural produce in the Northern region. Nolhivaram has relatively large area that is composed of diverse natural vegetation with coconut plants, wild Pandanus (*Pandanus amaryllifolius*) and number of hardwood tree species. South-eastern part of it has a large fresh water pond with mangrove species. Agricultural activities are carried out in homesteads as well as in designated farming areas in north and south-west side of the island. Due to this, Nolhivaram is considered a dominant agricultural island in the north with lot of households depending on agriculture for a good portion of their income. There are about 60 regular farmers with plots in the designated leased area in Northern and Southern side of the island. Variety of horticultural crops are grown here for home consumption and for sale in the market in Kulhudhufushi on weekly basis. Few selected products like banana, coconut and panadana fruits are also sent to central market in Male' via small cargo boats. The farmers have easy access to agricultural inputs from the Kulhudhufushi island.

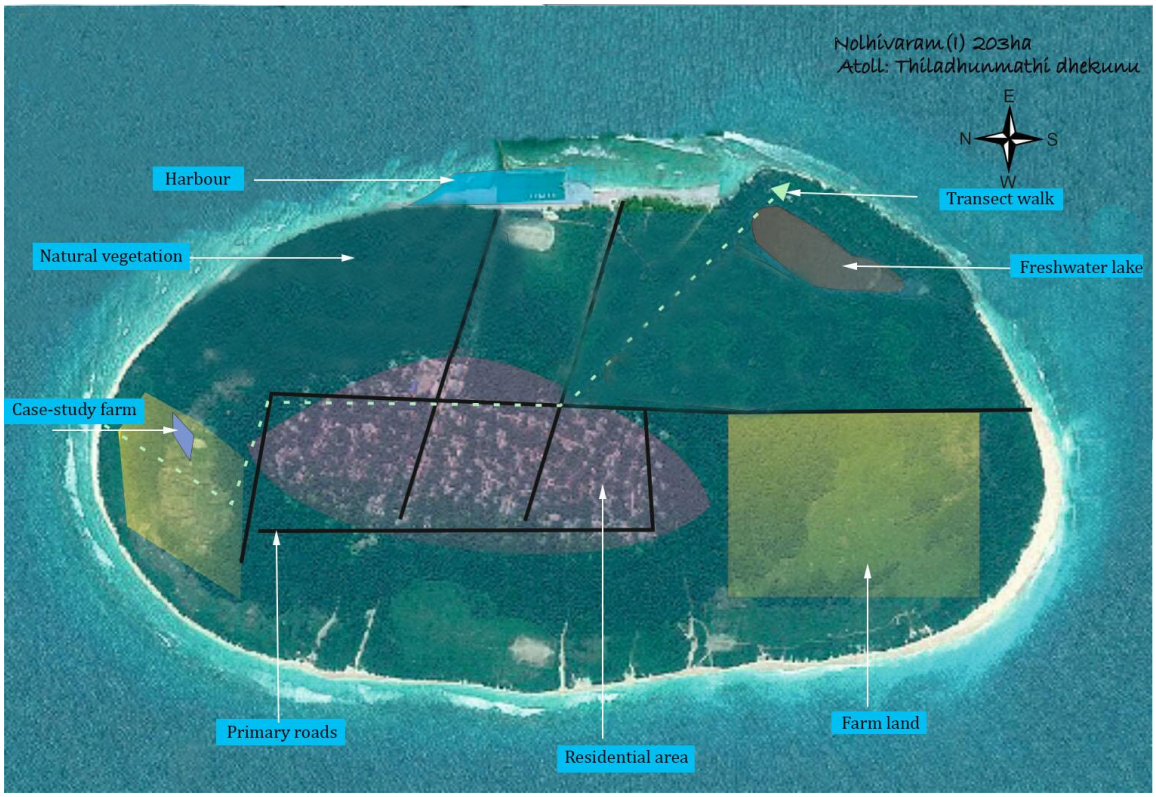


Figure 8: Case-study island of Nolhivaram. Image: 2018 Google SE

## *Case-study farmer*

The farmer is a 45 years old full time local imam (priest) at the island mosque and has family of three with two children who are in Male' with his wife. He has been farming for last eight years as part of his livelihood activity. He leases a 500sqm plot on annual basis from the northern agricultural area in Nolhivaram. He routinely engages with 20 or so neighboring farmers who has similar size plots in the area. Most commonly cultivated crops are brinjal, chili, watermelon, cucumber and butternut. Most of his produce is sold every Saturday at Kulhudhufushi local market. He has contract with the local ferry operators for transportation of his harvest to Kulhudhufushi. He has attended few farmer training programs carried out by MoFA and some of the trainings' duration exceed 3 months. Similar to most farmers in the island, he relies completely on synthetic fertilizer products and imported manure for his farm. Although he has taken steps to reduce the synthetic pesticide usage, it is still his main mean of pest control.

## *K.Kaashidhoo*

The island of Kaashidhoo is the 5$^{th}$ biggest island in the country and consequently one of the most prominent agricultural islands as well (Atollsofmaldives.gov.mv, 2018). It is named after the coconut plant for its abundance before they were gradually cleared out as population expanded. Subsequently, the surrounding ocean area is aptly named as 'Kaashidhoo kandu', meaning the sea

of Kaashidhoo. With comparatively fertile soil and rich vegetation, the island has a long history of farming. Being relatively close in proximity to Male' it has become one of the major hub for agricultural production. As can be seen in the Figure 9, it has got a large natural area with potential for agricultural expansion. Currently it is estimated that 55% of its total 299ha is used for agriculture. Additionally, the island has bustling household nursery enterprises that specializes in catering to needs of both agricultural and ornamental plants of resorts and growing market in Male'. This is a relatively new income generating activity for the country. As of 2017, the population of the island was 2000. As with all 200 inhabited islands in Maldives, Kaashidhoo has a school, judiciary office, island council, health center, a power house and other necessary facilities.

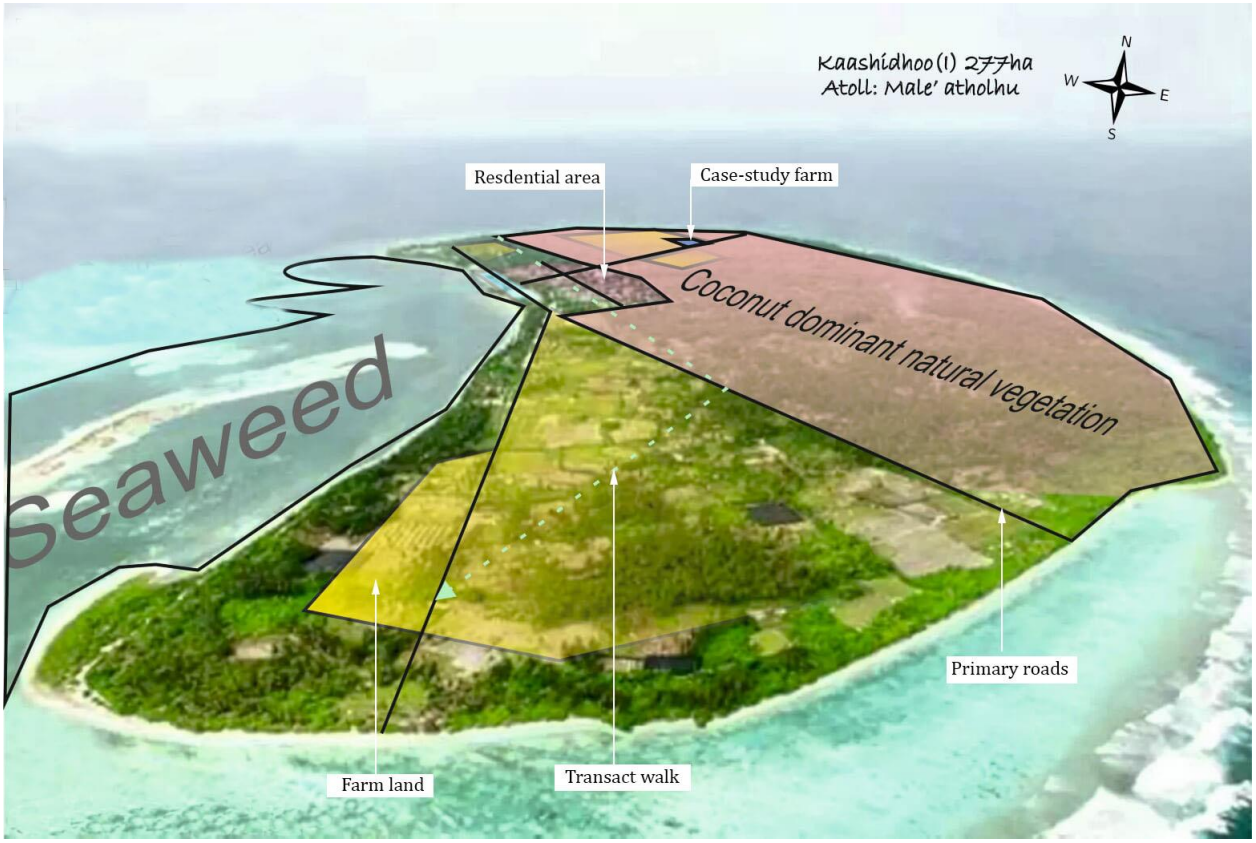


Figure 9: Cast-study island of Kaashidhoo. Image: Kaashidhoo island council

## *Case-study farmer*

The farmers a retired man who has been involved in farming for 23 years. He has four children with three of them living independently bring extra income to the family from working in Male' and in resorts. He has around 8400 square meter farming land. Large part of the land is grown with Breadfruit and banana, and the rest is used for producing lettuce, kale, spinach, cucumber, chili, and squash (*Cucurbita sp*). He does not have to pay any rental or lease fees for having the land to the island council as there is no strict land tenure system currently employed. Currently, any household member above 18years of age can claim a 950 square meter (10,000squre feet) area

through island council, provided that the space is available. The farmer manages nine such plots that are under his children and close relatives. The ownership is based on mutual understanding as not everyone claiming land necessarily has the desire to personally use it. He employs one fulltime worker and also hires seasonal labourers during land preparation and planting time. Despite his long-term experience in farming, he considers the work difficult and challenging in current times. This is mainly due to the challenges from pest and diseases and need to apply more inputs coupled with higher input prices.

## *Geography and Land area*

Geographically islands can be regarded as closed systems in terms of terrestrial activities where the coastal areas define the boundary due to isolation and relative land to ocean area. Most islands are group in a connected ring by reef called atolls. Some islands like Kaashidhoo is the exception for being separated from atoll ring and this makes it larger than most islands. Maldives has a total of 1192 islands in a chain of 26 atolls. Islands vary in size from 0.5 $km^2$ to around 5.0 $km^2$ and in shape from small sandbanks with sparse vegetation to elongated strip islands. All islands are low lying and none exceeds an elevation of three meter above mean sea level. The total land area (covering all islands) varies in time but on the basis of recent satellite measurements is currently indicated to be in the order of 300 $km^2$ (30,000 ha). Of the 1192 islands, 200 are inhabited. The remaining 993 islands are "uninhabited," of which around a 170 have been developed as tourist resorts, 47 as industrial islands and 32 as agricultural islands. The 26 geographic atolls are grouped into 20 administrative regions.

## *Climate*

Being on the equator, Maldives has a tropical climate with two monsoonal seasons where May to October (South-west monsoon) is the rainy season and November to December (North east) being the dry season. The 30 year (long-term) mean annual rainfall is 1972mm (Meteorology.gov.mv, 2018). However, according to the Maldives meteorological data for last 10 years, the average annual rainfall for the Northern region is lower than that of south with 1780. The average daily temperature is quite uniform all year round. The daily temperature can range from 29$^oC$ during day-time to 23$^o$ during the night. The highest ever recorded is 36$^o$ C in 1991 (Meteorology.gov.mv, 2018).

## *Soil profile*

Atolls in Maldives are formed from the gradual expansion of reefs which are primarily made of corals. When corals die and weather, their remnants form sand. Due to this, island soils are high in calcium carbonate and low in some micronutrients such as iron as oppose to the parent material composition in continental soils such as in the neighbouring India. Progressively as part of island development, with successive species of plant establishment, organic matter is added to form island soils. In this respect, islands are also highly dynamic systems that are always expanding with gradual addition of sand from the surrounding reefs (Aslam and Kench, 2017).

Soil test results (Table 1) show that, pH is neutral or slightly alkaline in all case-study farm islands. The alkaline pH is due to the calcium in the soil parent material. In the case of Kaashidhoo, the slight low pH might be attributed to presence of high organic matter from the addition of compost. High comparative N, P and K level in Mathikomandoo soil can be attributed to high manure and soluble synthetic fertilizer used during the previous season. The low level of P and K in Kaashidhoo and Nolhivaram suggest that soil nutrient level can be fluctuating despite the application of various NPK based fertilizers. Island sandy soil has low bulk density due to low density of coral sand (Wang et al 2012).

Table 1: Soil test results for pH and macronutrient levels at case-study farms. Tests done using NICE Field Soil Testing Kit by NICE Chemicals.

| Soil parameters | Mathikomandoo | Kaashidhoo | Nolhivaram |
|---|---|---|---|
| pH | 7.5-8.0 | 6.5 - 7.0 | 7.5 - 8.0 |
| N | M1 (250-350kg/ha) | L2 (120-244kg/ha) | L1(<120kg/ha) |
| $P_2O_5$ | M2 (20-25kg/ha) | L1 (<6.2kg/ha) | not detected |
| $K_2O$ | Between M2 - H1 (250 - 330kg/ha) | L1 (<60kg/ha) | M1(120-220kg/ha) |

L1-L2 = Low , M1-M2 = Medium, H1-H2 = High.

As can be seen from Figure 10a-c, the soils are rather shallow with less than two meters in most places and only organic matter content separates the productive soil horizons from mere sand. The measuring scale/stick in the Figures is 30 cm long from the top surface. The lack of clay particles makes the soil highly drained and, in most areas, the fresh water lens can be reached from a meter below soil surface. A freshwater lens sits atop dense salt water and this layer can deplete from high water extraction, especially during the dry season.

Figure 10 (1), Soil profiles: Soil profile from a fresh dug pit at the Nolhivaram farm (Source: This study)

Figure 10(b)-soil profile from a fresh dug pit at the Komandoo farm (Source: This study)

Figure 10(c)- soil profile from a fresh dug pit at the Kaashidhoo farm (Source: This study)

Smaller islands (<0.6sq km) are more susceptible to this practice. It can also be observed that generally larger islands have deep soil with thick fresh water lens compared to smaller islands (Bailey et al., 2014). All these factors increase the susceptibility of soil to leaching. The most important process that influences nitrogen management in sandy soils is nitrification. Because nitrate is a negatively charged ion, which is not held by soil particles, it is readily leached as water flows through the soil. Nitrates leach more rapidly from sandy soils than from fine-textured soils because sandy soils have a lower water holding capacity (Herzong and Konrad 1992).

## *Land management*

New agricultural plots are created by clearing the natural area leaving few trees. Trees with big roots are burned and completely uprooted. Perennial trees except for coconut and wild pandanus are rarely left in farming areas. With the exception in Komandoo, the cultivation area is left bare for most part of the year. Here, a fallow period of six to eight months is practised to the recently cultivated plots, while farmers shift to new plots. In Kaashidhoo and Nolhivaram due to the cultivation of crops all year around, soil surface is bare as a result of continuous weeding and recurrent disturbance of cropping activities. In these two islands, mulching using banana refuse was observed. Since there are no machinery or mechanical implements, soils are not fully tilled but designated pits and beds are prepared using simple hoes, rakes and spades. The pits position is changed within the plots from season to season. Field burning is a common activity in Komandoo

and Nolhivaram after the fallow period. Ash is spread over the field or placed in planting pits as fertilizer.

## 6.2 Ecological system

The composition of main biological elements in all three farms comprise of narrow group of horticulture crops belonging to two main plant families. These are namely; *Solanaceae* (chili, tomato, capsicum, brinjal) and *Cucurbitaceae* (watermelon, squash, cucumber, gourds, pumpkin). The cases provide a good picture of the crops cultivated in general, as can be seen in Figure 11, where chili, cucumber and watermelon are the most cultivated crop by farmers. The crops marked in 'dark grey' belong to the aforementioned two plant families.

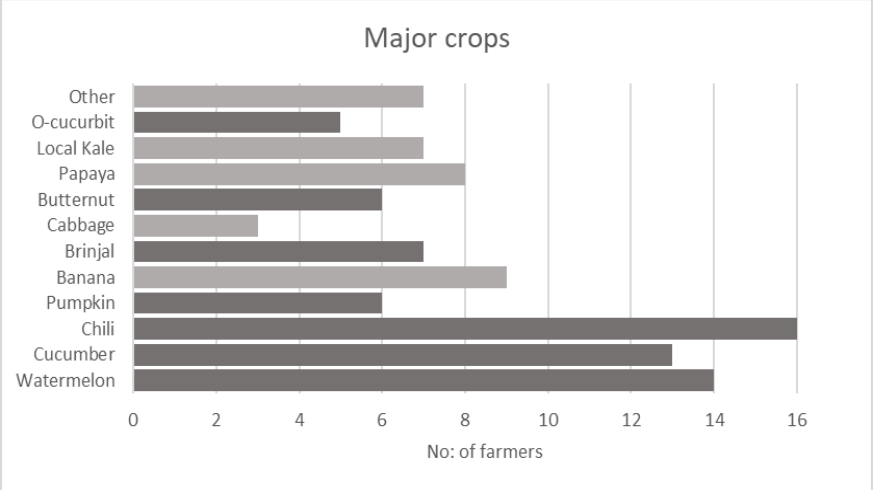


Figure 11: Main cultivated crops in Case-study farms and relative adoption among interviewed farmers. 'Dark grey' = either *Solanaceae* or *Cucurbitaceae*

Kaashidhoo farmer have the most crop diversity, while Komandoo farmer only focuses on chili and watermelon. From the general observations, crop diversity at inhabited island is increased in three aspects. Firstly, with the intensity of farming activities i.e. the proportion of the population involved in farming in an island. In this respect Kaashidhoo has more crop diversity than Komandoo and Nolhivaram. Secondly, the proximity to markets and in this respect Nolhivaram has relatively higher diversity than Komandoo. And thirdly, the size of individual farms. Smaller farms tend to prioritize most demanding crops for cultivation such as chili, watermelon and cucumber and thereby tend to deal in similar crops. Big farms such as the case in Kaashihdoo has comparatively more crop varieties.

Most of the planting materials (seeds, seedlings) are commercial hybrid varieties developed for intensive cultivation. These varieties often require extensive and continuous nutrient input for optimum performance (Jarvis et al, 2011; Cleveland et al, 1994). Since these hybrid crops were not tested in island soils during their research and development, they are assumed to perform poorly as can be inferred from farmers' reports.

The only two main crops of which local varieties were opted were chili and pumpkin. However, these two crops are facing 'unmanageable' pest and disease issues causing it to be phased out from cultivation in major agriculture islands including Nolhivaram.

Viral diseases, relating to a variety of host insects such as aphids, thrips, mites and whiteflies has reported to have high presence despite heavy pesticide use. It has been observed that increased requirement for pest control have farmers using nutrient applications inadvertently due to misconception regarding pest and disease diagnosis. For instance, Floral (an NPK soluble fertilizer) is occasionally used by farmers to control 'damping off (a fungal disease affecting roots of emerging plants and seedings) and some chlorosis from mites. Both chilli and watermelon were reported to be the most nutrient demanding crops by farmers (Figure 12).

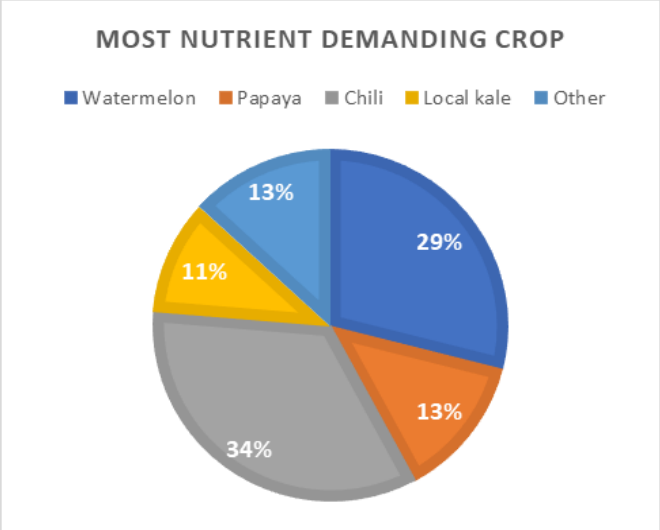


Figure 12: Common cultivated crops categorized according to nutrient requirement

The case-study farmers reported that they did not regularly grow beans in their farms due to low market demand. Only five of the interviewed farmers, cultivated legumes during the last two years. These farmers were also unaware of the nitrogen fixing potential of the legume crops.

It can be inferred from the general observation at farms along with the observed frequency and types of pest prevalence and reported pesticide usage, that there is low diversity of beneficial insects. Farmers themselves do not attribute any insects as beneficial for controlling pests. Additionally, hand-pollination of watermelon and pumpkin are routinely performed in the case-study farms, suggesting low presence of natural pollinators.

With regard to heterotrophic subsystem, naturally there have been low terrestrial fauna diversity in the Maldivian islands. Cats, small rodents, land crabs are the most prevalent terrestrial animals. Birds and bats are of specific interest to farmers as pests of fruit trees and emerging plants. Responding to the requests of island councils, MoFA regularly organizes expedition to bring down bats and crow population. However, these species have been a part of the ecosystem and they also spread plants and help in the build-up of soil (Wu et al., 2018).

There were no livestock in any of the three farms. This is characteristic of Maldivian farming system where traditionally some poultry species was present (Liebregts, 2007). However, wide spread rearing of cattle has never been the case. One of the interviewed farmers from Nolhivaram rear goats but reported that he was not using the manure for his crop component. Instead it is

discarded in to the natural vegetation near his property. There are around 10 goat-herding farms in Maldives and most of these farmers are not involved in crop production.

Decomposing component at the farms are not actively managed. Lack of knowledge can be one factor for this. Several activities at farms can be a hinderance to this part of the ecological system. For instance, since soil is bare and surface is dry for most of the day biological activities can be low. Moreover, field burning, in the beginning and in between seasons are commonly practiced in many islands, Mathikomandoo and Nolhivaram being among them. Burning can damage the soil structure, deplete organic matter and destroy huge portion of soil biota (Cowan, Smith & Fitzgerald, 2016). Apart from these, externally bought manure is heated for 10-15 minutes over fire at farms before mixing with soil. This is done to kill diseases without much thought to the potential quality degradation of the manure.

## 6.3 Management subsystem

### *Purpose*

There are many motivations for farming and often there are multiple factors that keep farmers in the profession. In small-scale farming where economic margin is often low as is the case with inhabited island farmers, non-economic factors such as enhanced community involvement, freedom from off-farm income and lifestyle benefits plays a stronger role (Howley et al, 2015). In the case of Kaashidhoo with its' long history of farming, farm ownership is a strong cultural norm as is the case for fishing in the small islands in south of the country. From the time spent at the farm in Kaashidhoo, it seemed that public status of having a stable farm venture is an equally, if not stronger, striving factor than financial gain. Of course, a farmer, at the very least must be financially stable but to be able to maintain the motivation in high trade-off circumstances as in Komandoo, multiple incentives must be in effect. Komandoo and Mathikomandoo with its limited land area and multiple industries like fisheries, local businesses competing for land space, farming may be carried out under high opportunity cost. For Komandoo farmer, farming activity brings the family together and keeps the tradition going. For him it gives a sense of flexibility in life that he does not get from his routine job at the island. This factor had a strong influence on Nolhivaram farmer as well. He also enjoys participating in the weekly market activity in Kulhudhufushi with neighbouring farmers. It has become his lifestyle. In distinguishing purpose, a strong indicator is to look in to the occupation in terms of its adoption for financial dependency. From this study 75% of respondents consider farming as a secondary income source and the remaining respondents agree to having financial assistance from other family members on regular basis (Figure 13).

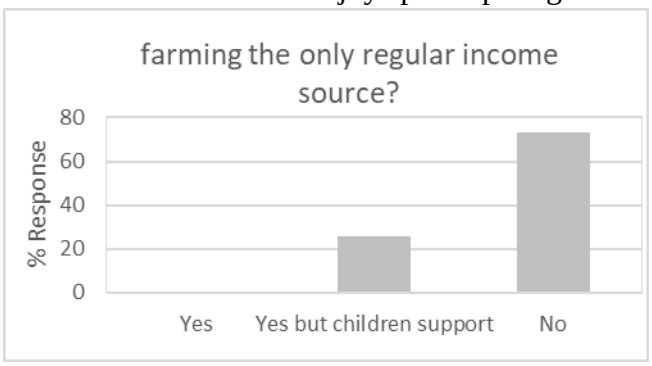


Figure 13: Income generation in relation to farming.

### *Innovation*

For understanding innovation, it is important to recognize the knowledge system that is a key tool for farmers (Pascucci & de-Magistris, 2011). Traditionally when agricultural activities were for subsistence, it was carried out with little or no external input which is reflected on the knowledge that have been handed down. In current times however, since the advisory services came into being, the dichotomy between traditional farmer knowledge and researcher/extension officer knowledge has been high. This difference could be due to the attempt to emulate conventional farming practices in a drive to commercialize farming. Farmers have benefited from this through quick solution for problematic issues like newly introduced pests, marked yield differences in hybrid varieties could be observed early on through synthetic nutrient inputs which were alien to farmers for a long time. This process has however, created dependency to authorities (MoFA and Funding

agencies like FAO) and lowered the innovation capacities of farmers. Top down approach in technology transfer is still the main mode adopted. Early approaches such as farmer-field school programs were an attempt at bridging farmer and extension officer knowledge, but these programs were highly structured with extensive syllabus and less focussed on farmers to define and solve their own problems.

Currently, intensive input-use is evident in most form of innovation that farmers claim. For instance, different mixtures of synthetic fertilizers are applied during bed/pit preparation for improving yield. If marked differences in yield is observed, this practice is attributed as the cause, despite lack of scientific processes behind it. Fertilizer mixing beyond recommended levels is evident in all three case study islands. This is because farmers may lack knowledge on diagnosing problems related to nutrient deficiencies, identification of fertilizer types needed, nutrient movement and retention in soil, and application methods for special fertilizers such as folia fertilizers (Figure 14). The understanding of innovation has to be broadened from a sole focus on technologies and yield maximization to include socio-economic, cultural and institutional practices (European Union, 2015).

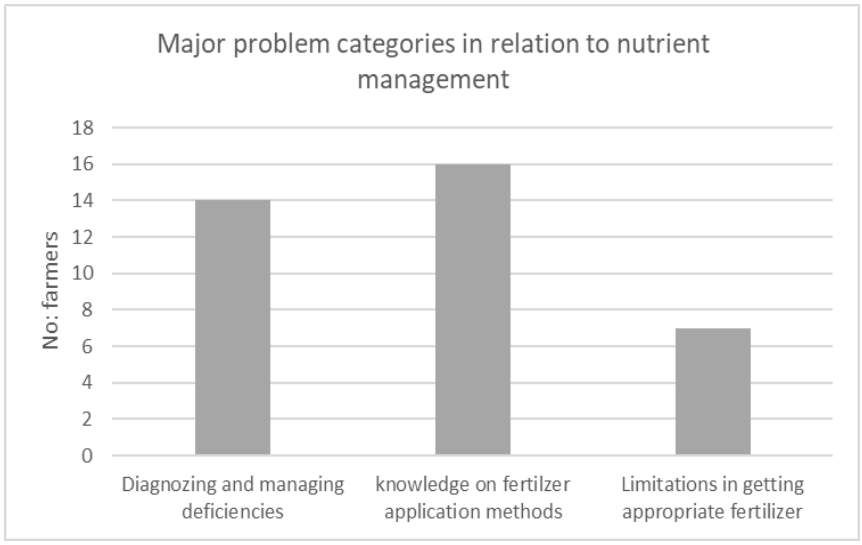


Figure 14: Major problem categories in relation to nutrient management

## *Inputs*

Input sources in inhabited island farms is rather simple due to inputs mostly being external in nature. Three main input types, which are knowledge, labor, and variable inputs have been investigated in this study. Financial capital and time as inputs and a resource is discussed in 'resource allocation' section. All the three case-study farmers, have attended only one advisory program of less than two weeks since they began farming. Therefore, most of their knowledge is grounded in traditional practices. From Figure 15, it can be seen that farmers identify themselves to have 'self-taught' as their main knowledge source. Hence, 80% of farmers has never heard of agroecological farming methods such as agroforestry, organic farming, permaculture or biodynamic farming (Figure 16).

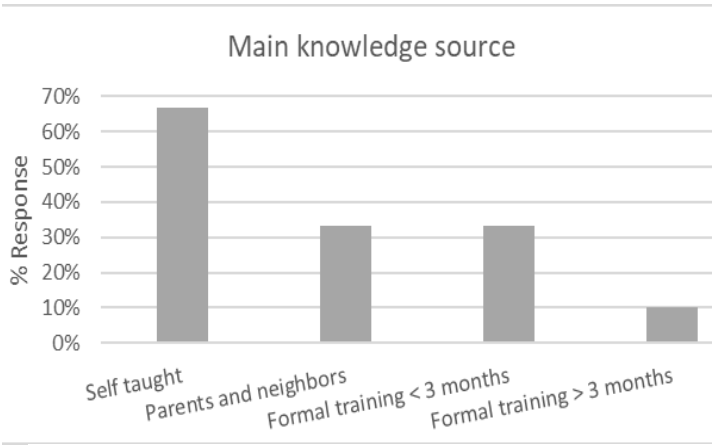


Figure 15: Main pathway or source of knowledge

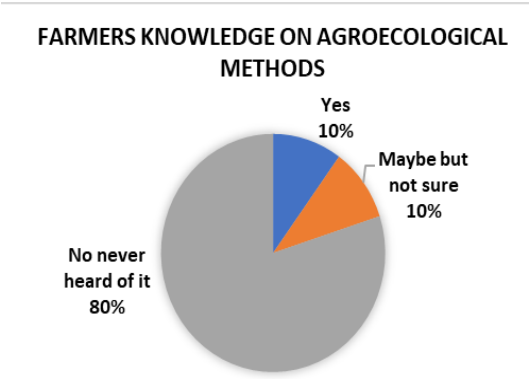


Figure 16: Farmers knowledge on agroecological practices

Even though farmers are used to handling variety of fertilizers, most farmers can only identify N, P and K as plant nutrients (Figure 17). Additionally, some farmers find it hard in distinguishing fertilizers from pesticides as commonly farmers tend to group them together with the term 'beys' (medicine). Apart from that, 90% farmers who reported having a regular contact (advisor) for technical information identifies input sellers as their main knowledge source. MoFA has extension officials who are on-call for advisory needs of farmers, however, some farmers stated that it was more convenient to find information from the shops selling inputs in Male' or Kulhudhufushi. Even though this might not be the best course of action; this dependency on shops is crucial since English literacy level can be low among famers and therefore require assistance in translating

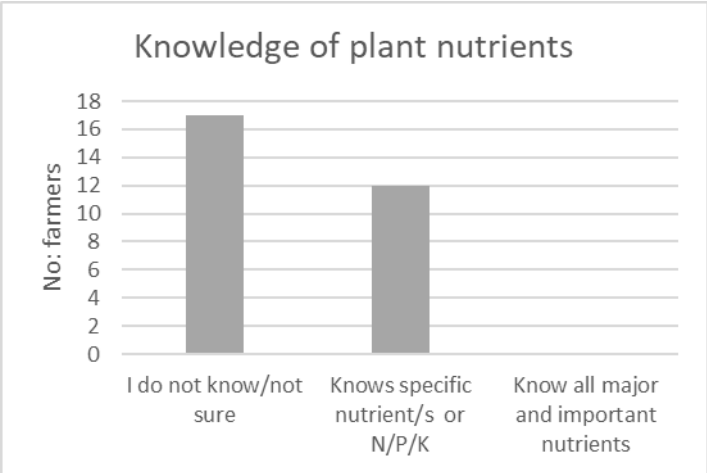


Figure 17: Farmers knowledge on plant nutrients

packaging labels on the inputs. Farmers also reported to have poor knowledge on individual plant nutrients. Since, farmers know-how on the contents of fertilizers is mainly limited to their knowledge on N, P and K, many tend to attribute quality of fertilizer on its brand name or common name than its contents (Figure 17).

With regard to energy use, electricity is rarely used on farms. Irrigation being the main energy demanding activity is carried out using petrol pumps. However, since production sites are either on homestead or near residential area, farmers could access to electricity when needed. Electricity shortage was only an issue for the case-study farmer in Komandoo, since the farm is in nearby uninhabited island of Mathikomandoo.

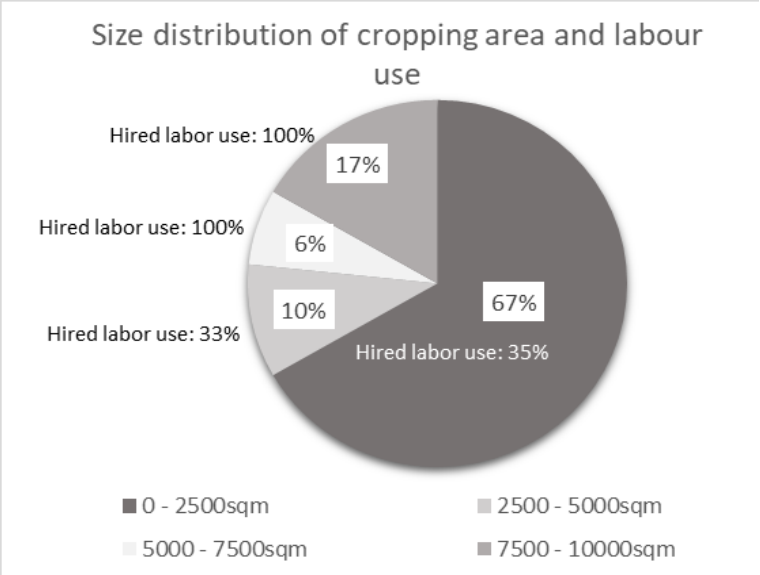


Figure 18: Size distribution of cropping area and proportion of labour use for each size category

Generically, it is uncommon to have hired labour in small farms. However, in Maldives, hired labourers are regularly employed in large farms. Thus, it is common in Kaashidhoo island. In fact, among the interviewed farmers, all the farms that were larger than 7500m$^2$ (while less than a hectare in size) employed foreign labour (Figure 18). Labour at farms are unskilled foreign labour; the only type of fulltime labour employed.

Main fertilizer and manure inputs used by case-study farmers with reported use from other farmers are shown in Table 2. Varieity of synthetic fertilizers are popular with some being used by more than 70% (Floral) of farmers. Floral is among several other fertilizers that are water soluble NPK compound mixtures (marked '*' in Table 2) specialy designed as foliar fertilizers. It can be noted that farmers tend to prefer fertilizers with high NPK ratio such as 20:20:20 lest they have mis-diagnosed and apply less than required. Morever, hydroponics special fertilizers (Hydrocomplex and Alberts' solution) are quite frequently used in soil cultivatoin. Also, despite the lack of livestock presense, farmers have developed preference for using manure on regular basis (87%).

Table 2: Fertilizer and manure inputs used by case-study farmers with reported use from interviewed farmers. * = NPK soluble foliar fertilizers

| Commercial name | Description | Synthetic (chemical)/Organic (natural) | Imported | Total reported % |
|---|---|---|---|---|
| **Cowdung** | Manure from India or Srilanka | Organic | yes | 87% |
| **Unigrow** | Compost mix with manure | Organic | yes | 33% |
| **Fertilplus** | Organic compost (4 3 3) | Organic | yes | 23% |
| **Yaramila** | NPK granular 12 11 18 | Synthetic | yes | 63% |
| **Floral*** | NPK 20 20 20 soluble | Synthetic | yes | 73% |
| **Supernex*** | NPK 20 20 20 soluble | Synthetic | yes | 23% |
| **Nitrophoska blue** | NPK slow releasing fertilizer | Synthetic | yes | 13% |
| **Farivalhu 1/2/3** | Chemical mixture specific to each growing stage developed by MoFA. | Synthetic | Yes but mixed locally | 23% |
| **Ammonium sulphate*** | Ammonium sulphate | Synthetic | yes | 23% |
| **Albert's solution*** | Hydroponics ready fertilizer mix | Synthetic | yes | 13% |
| **Hydro complex** | Hydroponics fertilizer mix | Synthetic | yes | 26% |
| **Urea** | Urea | Synthetic | yes | 23% |
| **Potassium** | P sulphate | Synthetic | yes | 13% |
| **Baus fruit/vegetable** | Synthetic compound NPK fertilizer | Synthetic | yes | 20% |
| **Other (Growgreen, Growmore*,** | NPK foliar fertilizers | Synthetic | Yes | 19% |

Majority of these inputs listed in Table 2 are external to the system and its origin can be traced to agrochemical producers in Europe and Asian countries (Mostly, India, Thailand and China). Due to the high dependency on external inputs, local resource use is at minimum and in some cases, non-existent. Figure 19, describes farmers' opinion on local resource use such as local crop varieties, home-made pesticides, natural fertilizers etc. While few farmers were positive about the local input products, most believe it is too time consuming and needs more effort. Others believe that nutrient recycling is not sufficient since the soil is too degraded. There were also farmers who suggested that it is always better to buy ready- made fertilizer if they were available and affordable.

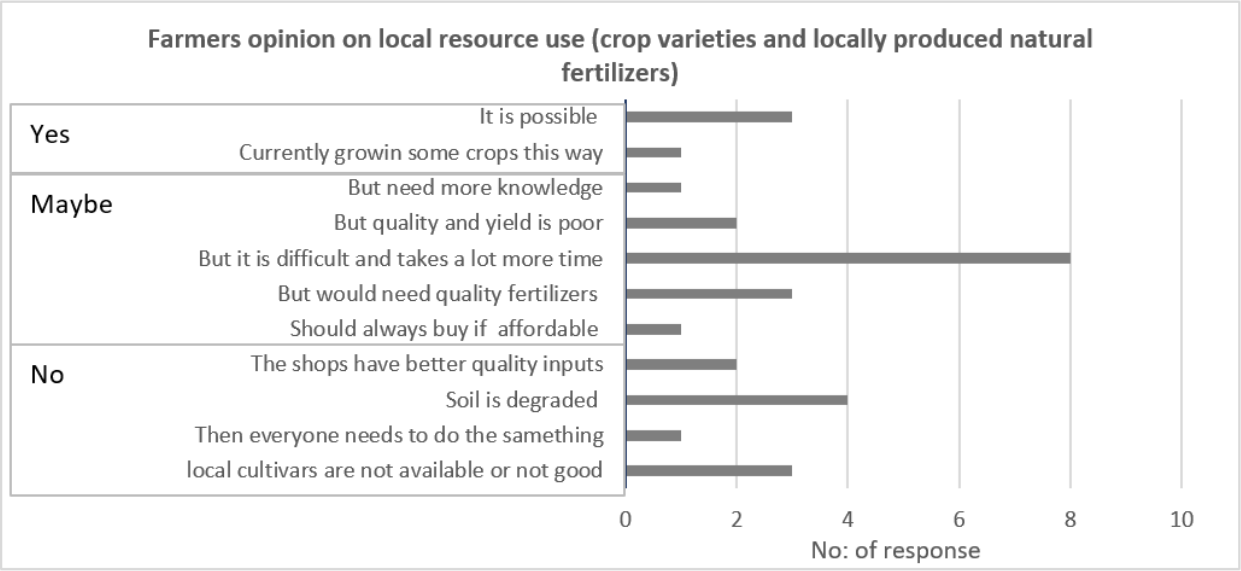


Figure 19: Farmers opinion on local resource use

## *Outputs*

Quantitative information was hard to obtain regarding outputs (e.g., crop, straw) either at farm or at regional level. The case-study farmers do not keep much record of sales or yield. MoFA keeps crude record of inputs coming in to Male' local market from the atolls. Since most produce is sold as fresh, not much information is available from Kulhudhufushi local market. Farmers however reported using 5-10% of yield for home consumption. In terms of output at farm level, externalities from agrochemical use can be considered. However, there is no analysis in any case-study islands (or any other islands) on contamination of soil, groundwater or air pollution etc. However, in main agricultural islands like Thoddoo (in the central Maldives), ground water has become unusable due to contamination from agrochemicals including manure and depletion due to high extraction (FAO, 2017).

## *Resource allocation*

The case study farmer in Komandoo, allocate sufficient time for the overall farming activity during the three months of production. As a seasonal farmer, he has a lot of time for preparation. During the cropping period, he has to take daily trips to his farm in Mathikomandoo by a small motor dingy from Komandoo. In the case of Nolhivaram and Kaashidhoo, the farmers spent regular hours at the farm on daily basis and more time during weekends. All three farmers do not keep full record of farm activities or financial records except for receipts of larger procurements. It was observed from interview that considerable time is spent on restocking supplies for production, and not enough time is spent for evaluations and reflections from previous seasons. According to them, while little improvement from deep analysis could help to optimize activities, the trade-off of time from other livelihood activities is too high. This trend of settling with realized economic gain while

underscoring potential gain from marginal improvement seems to be common among the farmers. This perception is seemed stronger in seasonal farmers like the Komandoo farmer.

Farmers do not pay for irrigation except as fuel cost in cases where pumping is involved. Since, land leasing policies are determined by island councils, it varies between islands. Land lease fees were payable in Nolhivaram and Komandoo (Mathikomandoo) and it was between 50 - 100 Maldivian Rufiyaa (3.5 – 6.5USD) for 460-500 square meters per month.

With respect to farm expenses, the main cost is incurred in buying seeds, pesticides, manure and fertilizers. As farmers use hybrid varieties, seeds are procured on regular basis except for pumpkin and some varieties of chili. Watermelon, cucumber and papaya are considered expensive seeds by

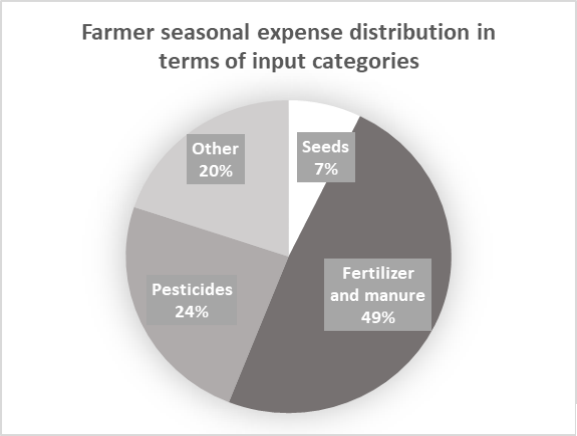


Figure 20: Seasonal expense distribution in terms of input categories

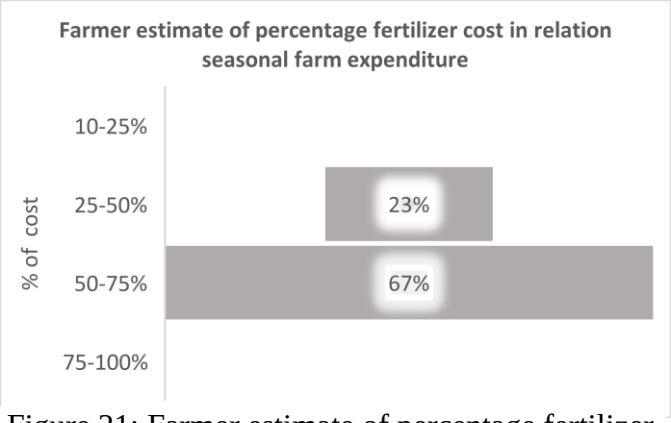


Figure 21: Farmer estimate of percentage fertilizer and manure cost in relation to seasonal expenditure

farmers.

In fact, fertilizer expenses take largest portion of the total seasonal expenditure expenses (Figure 20). In cases where labour is employed, it seems to take bigger portion of the farms expenses. When asked to estimate the percentage of seasonal expenditure for nutrient needs (fertilizer, manure etc) in relation to total seasonal expenditure, 67% report having 50-70% of their cost allocated for nutrient needs (Figure 21). One of the seasonal recurring pattern most farmers observed was the need to use more fertilizers year by year to generate the same yield as the previous years. This trend suggests the decline in yield response to fertilizer or rapidly decreasing soil fertility. However further in-depth analysis is needed to confirm this.

in order to understand the alternative options available for farmers as replacement for synthetic fertilizers, transect walk, farmer discussion were carried out. From the transact walks, large availability of raw materials such as cocopeat, biomass from coconut, banana and papaya refuse, dry leaves, ash, household refuse, seaweed, and in some cases fish-bone meals for local compost making could be observed which could be accessible to farmers. These materials are also recognized and identified by farmers during the interviews as being available from the island environment. According to the interviews with island council members, councils have no

restriction for farmers in using them. Since farms are located near natural areas, plant refuse and other organic matter are openly allowed for use. Also, relatively big farms, such as the case in Kaashidhoo where banana and papaya are cultivated, generate significant biomass which could be used for mulching. During the interview, the president of Kaashidhoo island council quoted as such:

*''People who remove plant refuse from the natural vegetation/forest area are actually doing a service for everyone. They are also free to collect organic materials from the waste collection area''*

Since the supply of materials for composting seemed to be not a limitation, participants were asked during a group discussion at the case-study island to identify and rank the challenges for composting according to its difficulty for adoption. The aggregate results are justified based on frequency of ranking number allocated by each participant to a given challenge. Determining nutrient level in compost, timeliness, difficulty in application are among the identified issues in both discussions. It is clear that participants identified lack of knowledge on composting as their main challenge. While some issues like bad odour and subsidies seems to be controversial among farmers in two islands most agree that lack of materials does not include among the biggest challenges (table 3).

Table 3: Farmer identified and ranked the challenges to composting at farms. 1=Biggest challenge, 10=Least challenge. Felidhoo* was used as reference island.

| **Reasons/challenges** | **Justified ranking** | | |
|---|---|---|---|
| | Komandoo (n=20) | Nolhivaram (n=15) | Felidhoo* (n=18) |
| Lack of specific knowledge on composting | 1 | 1 | 1 |
| Bad odour | 2 | 8 | 10 |
| Hard to determine the nutrient content and its level | 3 | 2 | 6 |
| too costly to make | 4 | 7 | 8 |
| Difficult to store and re use | 5 | 5 | 3 |
| No quality standards | 6 | 3 | 9 |
| Hard work and takes lot of time | 7 | 2 | 4 |
| Difficult for application and use as part of a nutrient schedule | 8 | 6 | 7 |
| Not sufficient materials available at the island or farm area | 9 | 10 | 10 |
| No subsidies | 10 | 9 | 2 |

## *Operations*

The routine activities at Kaashidhoo farm is managed by the permanent foreign labour while the owner oversees the operations. Among the general farm activities, irrigations and fertilizer application are the important ones which sometimes are carried out daily (fertigation during irrigation). Contrary to the traditional farming and considering high rainfall, irrigation is a regular activity sometimes carried out twice daily. This is due to the poor water retention capacity of island soil. Lack of organic matter may also contribute to high drainage. From the data collected on fertilizer use it can be noticed that 'fertigation' has become a common practice carried out during irrigation. This is practiced by 90% of the interviewed farmers including the three case-study farmers, at least on a weekly basis. From Table 2 (above) it can be seen that three types of common NPK based soluble synthetic fertilizer are used. Foliar sprays combined with animal manure in the specific phases of a crop has become the common repertoire in nutrient management. Animal manure (mostly cow dung), is mixed with soil in prepared beds and pits prior to seed sowing or planting. Interestingly, some farmers seem to also implement this practice in newly created farming plots suggesting that inherent soil nutrient levels are not deeply considered.

In relation to key practices associated with nutrient management, only Kaashidhoo farmer practiced composting occasionally. The amount he produced was supplementary as a large portion of nutrients was still procured in the form of synthetic fertilizers. However, from the graph (Figure 22) it can be observed that composting is not a regular practice at the farms in general. As for mulching, some farmers incorporate the remains of watermelon crop or cucumber (green manure) back in to the soil. But, this is also not a widely used practice. Leaving crop after harvest is perceived as drain on soil nutrients with chance of spreading diseases. Mulching is only common in fruit crop management such as papaya and banana where plant refuse from banana and coconut plants are placed in the planting pits. Since most other vegetable crops have shorter life span, mulching would make extra work and it can host pests and diseases. Thus, mulching is considered a low return activity, and many practice it as part of waste management processes than for its nutrient and water saving services. Apart from that, crop rotations are practiced in some level within farms despite the smaller size. Farmers usually switch plots in cultivating routine crops to reduce pest issues. Even though plots are small, the usual pattern of planting is more close to intercropping practice than mixed cropping.

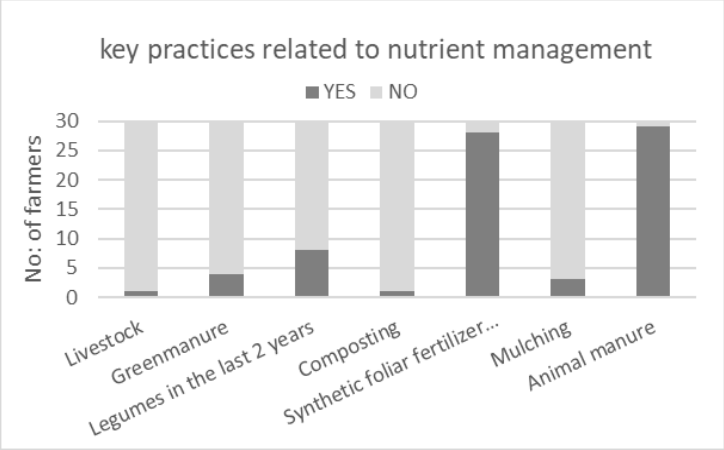


Figure 22: Key practices related to nutrient management

Farmers regularly deal with middle-man, in most cases, a boat owner in negotiating prices for their crops. All three farmers reported having very little control over setting prices since they do not have the quantity or facility to store produce nor means to transport directly to main markets of Male' or Kulhudhufushi (Figure 23b). This is the route for farm products to reach the markets in Male'. In Nolhivaram, however, farmers are directly involved in selling produce in weekly basis at Kulhdhufushi (Figure 23a). Prices are adjusted during the day to sell-off all the produce by the end of the day.

Figure 23(a) - Nolhivaram farmers transporting produce to Saturday market in Kulhudhufushi (Source: This study).

Figure 23(b) - Kulhudhufushi local market. Here farmers from neighbouring farming islands gather every Saturday to sell their produce (Source: This study).

## 6.4 Cultural forces

Farming history, age of farmers, family dynamics, cultural disposition to farming are important factors that could influence the practices and direction of agroecosystem. From the data it can be identified that most farmers are above 45 years old (Figure 24). Also, the proportion of female farmers as owners or managers are significantly low. Both these factors have important implication for farming in the future. Apart from that, youth participation in both agriculture and fisheries sector has been declining. From the discussions with school students, it can be understood that students do not consider agriculture field as they consider

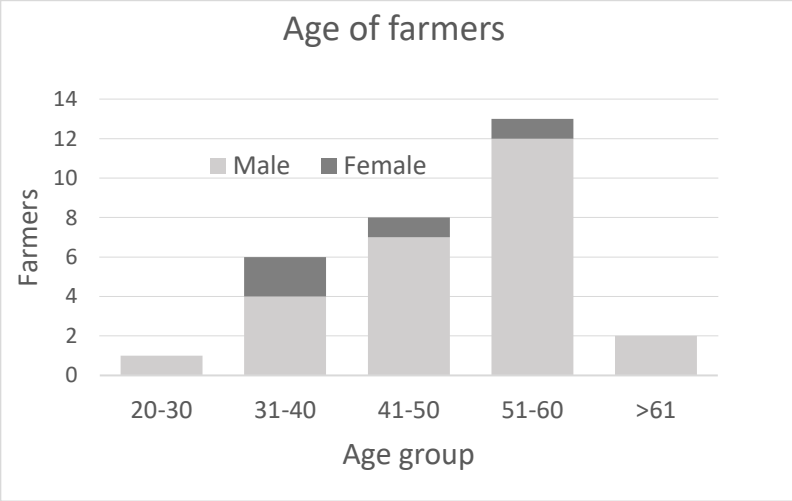


Figure 24: Age of farmers grouped in age categories

other popular professions such as the civil service sector, police or medical profession. The three main reason for this lack of interest are: firstly; the societal values on primary sectoral work (agriculture and fishery) as having low knowledge and technical training requirement from formal education. Secondly, there are very few successful sole agricultural enterprises that can provide the necessary aspiration for young generation coming out of secondary education to consider agriculture as a viable long-term career option. Thirdly, the sectorial education on agriculture/rural development is non-existent in the Maldivian educational system and there are no higher education institutions offering certificate or undergraduate level courses in agriculture or food production. The cumulative effect of this is evident in the demographic pattern, where agriculture, despite, still being one of the main livelihood activity in inhabited islands, has not been successful in reducing the migration of youths to the capital city Male'. Even for young entrepreneurs to take up farming, face several challenges. The main challenges, apart from the lack of agricultural knowledge, are the inaccessibility to credit schemes and difficulties in obtaining productive land in due to limited land availability. Commercial bank loans for agriculture amount to a negligible proportion (less than 1 percent) of the total loans granted to all the major economic groups (FAO, 2017).

## 6.5 Socio-economic perturbations

Land tenure system, transportation, value-addition, are some of the key factors that can effect agroecosystems functions. Four government authorities work on land distribution and allocation namely; the Ministry of Agriculture, Ministry of Environment, Ministry of Housing and Infrastructure and Ministry of tourism. As briefly discussed above in section, the island council is the primary authority on land allocation in inhabited islands. In spite of this, according to the interviews with island council members, due to overlapping of sectoral mandates and non-specificity of authority, there are frequent complications in complying with laws when making decisions for farming needs of the island. From the case-study islands, it is observed that land distributed for farming often does not have specific owner. In Kaashidhoo, land is registered to the household, while in Komandoo, plots are allocated on seasonal basis depending on the number of applicants. Since, these plots do not remain with the same grower every year, hence, little is done to maintain and improve soil fertility (FAO, 2017).

Looking at economic potential of agricultural produce, there seem to be little opportunities for value addition. Low quantity, insufficient post-harvest handling and processing infrastructure and lack of specialization of producers seem to be the main contributing factors. Lack of farmers' cooperatives could also be a contributing factor. While there has been considerable effort from MoFA in establishing farmer cooperatives around 2007-8, only one active institution (Hulhumeedhoo Cooperative Society), remains now (MoFA, 2018). The aim of the cooperatives was for farmers to join resources in facing major challenges such as transportation of produce and procuring inputs. Transportation however, remain a big challenge for individual farmers. Market in-accessibility worsened by poor transportation infrastructure led farmers to increasingly rely on middle-man. Narrow market range coupled with reliance on imported foods for major consumer

segments such as tourism sector severely limit marketing options. Being a majority importing country, the markets including departmental stores and local markets both in Male' and Kulhudhufushi are stocked with variety of imported agricultural products ranging from fresh produce to value-added products. Farmers reported receiving low prices due to high competitiveness of from cheap alternative options.

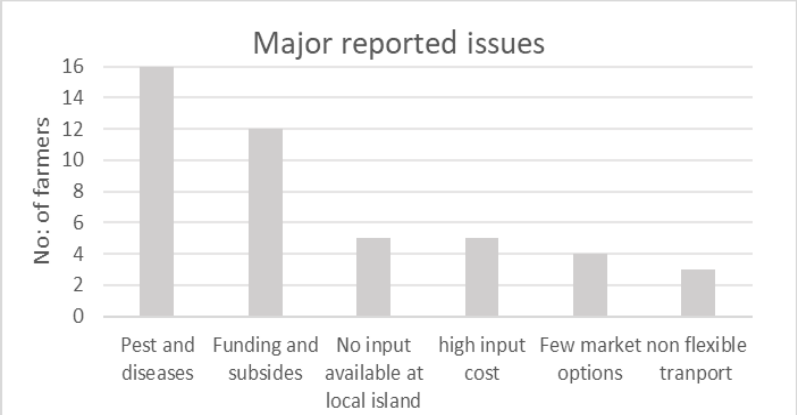


Figure 25: Major challenges facing farmers.

Despite the increased adoption of technologies and inputs, farmers are facing variety of challenges (Figure 25). Pest and diseases, together with lack of credit facilities have been the most important challenges.

Table 4 below, shows general opinion on how farmers find agricultural work in current times compare to when they started farming. It can be seen that, majority of them consider farming to be more challenging in current times due to pest and diseases and increasing requirement for agrochemicals.

Table 4: Farmers' opinion on agriculture work in current times compared to when they started farming

| **Opinion** | **Main reason/s** | **Total response** |
|---|---|---|
| Easy (3) | But more diseases now | 1 |
| | Increased knowledge and experience | 2 |
| Not easy/not difficult (17) | But high work load | 1 |
| | But more input/fertilizer needed now | 4 |
| | No specific reason | 6 |
| Difficult (15) | No specific reason | 1 |
| | because high work load | 1 |
| | because more input/fertilizer needed now | 5 |
| | Because more diseases | 8 |

However, when looking at farmers prediction of the future against main activities of farming, they are optimistic about economic return and productivity from the land but foresees no improvement in the use of local resources in next 5 years (Figure 26).

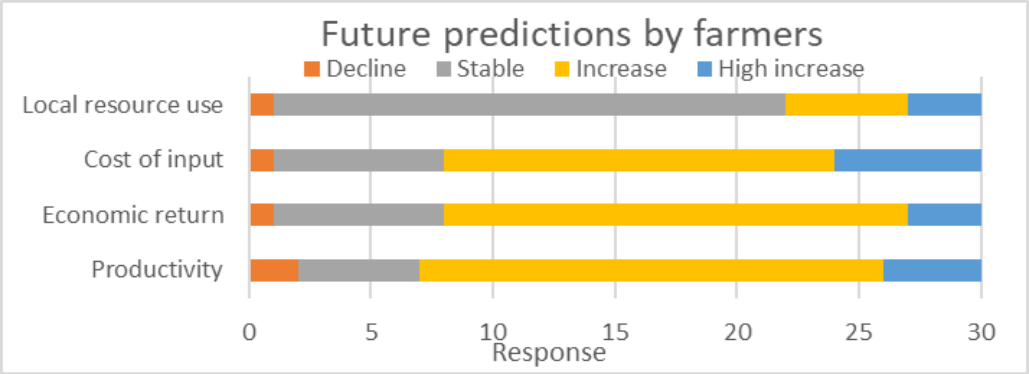


Figure 26: Farmer predictions for next 5-years on common elements of farming

## 6.6 Natural perturbations

Th Global Environment Facility (GEF), indicates that no settlement on the Maldives is entirely safe from the predicted impacts of climate change (Sovacool, 2012). It also notes that the Maldives is the "flattest country on earth" and "extremely vulnerable" to climate change, so much that 85% of its geographic area could be underwater by the year 2100 if sea levels rise under more extreme projections (Sovacool, 2012). A recent study on landform changes reveals net erosion of atoll islands in the observed area. Erosion was prevalent on 45% of islands with the remaining islands being stable. A relationship between island size and landform change was identified with smaller islands such as Mathikomandoo (<10 ha) dominated by erosional responses as time progress while larger islands (such as Kaashidhoo and Nolhivaram) dominated by accretion (Aslam and Kench, 2017).

Maldives has taken up hard adaptation measures such as building coastal walls, land reclamation etc. rather than soft measures such as improving mangrove diversity (Sovacool, 2012). However even these measures would not be sufficient in times of natural disasters. The agriculture sector was one of the worst hit by 2004 tsunami. Salinization of soil and salt water intrusion into the aquifers severely damaged crops, trees and plants in all the affected islands. The tsunami damaged the crops in 2000 farms, destroyed backyard crops and agricultural tools in 12000 homesteads, and damaged more than 700,000 fruit trees in the inhabited islands. The damage to land and groundwater resources was reported as severe in 35 agricultural islands, and saline water intrusion affected 112 inhabited islands (Ministry of Planning and National Development, 2007). A recent study by Bailey et al. (2014) on freshwater resources indicate that while many of the atoll islands are expected to have a measurable freshwater lens during the majority of a long-term climatic period, significant decreases in thickness can occur during the months of the dry season, with

complete depletion occurring for small islands. Of note was the observation on general decrease in lens thickness, approximately 2–4 cm/yr, over the 14-year period in the northern regions of the Maldives. If continued at current rates, these trends can have a significant impact on groundwater resources.

## 6.7 Evolutionary forces

Evolutionary forces are gradual progressing elements that effect evolution of the agroecosystem. These factors can help the system co-evolve or can be obstacle to the progress and they can arise from within the system environment or across the system boundary. In the ecological sense, since the adoption/use of hybrid varieties there has been marked decrease in the cultivation of local crop varieties. There has been little effort put in to saving the local crop varieties posing a huge challenge for biodiversity. Also, there has been a rising nursery plant production activities as homestead an operation. Women are more involved in this activity and products are targeted for resort and regional markets. While this brings people closer to cultivation practices, it is another avenue for fertilizers and does not add to the food security aspect since the focus is on ornamental crops.

Apart from that, Maldives has been going through rapid change that has modified various legislative elements, transformed institutional hierarchies within the last 10 years. One of the notable change is to the MoFA mandates where by policy objectives have become short-term oriented - usually 5 years. Also, disposition towards more tangible aspects in sectoral development can be observed. These includes preference for input subsides over infrastructure building. Moreover, due to the competitiveness and conflict of ideologies continuity of goals has not been seen in last 3 democratic periods and recurrent alteration to regulatory and licensing measures are frequent. According to the stakeholder interviews, these factors pose a challenge to the implementation of various agri-development projects. In the 7$^{th}$ National Development Plan, only 5 goals (from total 20) were set for addressing sustainability for three sectors, i.e., agriculture, fisheries and forestry (Ministry of Planning and National Development, 2007). While the goals were specific in most cases, only one goal broadly sates ‘ensure sustainable development of agriculture and forestry’ indicating limited focus on primary sectors. Moreover, with the rise of tourism sector and tourism related activities in 2006 a legislation ‘Regulation on the Protection and Conservation of Environment in the Tourism Industry’ was adopted while no such regulation exists for agriculture, fisheries or rural development. The only legislative material close to environmental protection in agricultural land use is ‘Maldives land act’ which was enacted in 2002 but does not specify land management nor tenure regulation for agriculture. In the, Agriculture Development Master plan of 2010 – 2025 sustainable development approach has been masked by the focus on productivity improvement. While this plan acknowledges the fragility of Maldivian agroecosystem, it has been formulated without analysis of the carrying capacity of total available cultivable land in the country (of merely 3000 hectare) (MoFA, 2009).

With a focus on enhancing commerce and productivity, agri-input business activities have increased rapidly with the four biggest agri-input suppliers only having started in the early 2000’s.

While this may be a good step in the broader sense of economic and production stability, it also enhances the pressure on farmers to opt for input intensive farming practices. Currently many islands have local shops providing various plant nutrient mixtures and other agrochemicals, and this is expected to increase in the future. Non-judicious use of products can also be expected to increase since most farmers are not equipped with necessary knowledge, and mainly rely on distributers for advisory needs.

On the positive note, there have been huge focus on waste management in the recent years. Island level regulations on waste management have been formulated by the island councils with the support of local authorities. Recycling of local resources through merging waste management with agriculture can create positive development. While some island like Nolhivaram has yet to adopt island level waste management program, both Kaashidhoo and Nolhivaram has designated areas for waste with some level of waste separation. Organic materials generated, especially on big islands like Kaashidhoo and Nolhivaram essentially could provide enough nutrients for agricultural uses.

Another positive factor is the growing public awareness on the consumption of healthy foods and changing of consumption habits. Traditionally, consuming fresh vegetables has not been part of the Maldivian food habits as it mostly consisted of fish, coconut and spices (MoFA, 2009).

## 6.8 SAFA Analysis

Sustainability assessment was carried out for case-study farms using the SAFA small holder application (Figure 27). The results give an overall picture of farming practices highlighting the status of farm across the sustainability dimension. When the performance is viewed, a comprehensive idea in relation to sustainability of small holder production of the study region can be inferred. As can be seen in the Figure 27, the general direction of sustainability is similar among the studied farms. It shows that, farms are doing better with respect to social dimension. Themes needing immediate improvement (hotspots) that are common to all farms are, corporate ethics, holistic, management, atmosphere, land, biodiversity, water and product quality and information (score 1 in the figure). All these themes belong to either environment or governance dimension of sustainability. This reflects on the current farming practices and its potential effects on the environment and quality of farm management. Key themes such as ‘farm holistic management’ are showing poor performance in all three farms. On a closer look, small difference between farm performances can be observed with Kaashidhoo case showing slightly better over all performance compare to other two islands. The situation of economic dimension is not fully represented due to non-applicability or lack of data provided by the farmer during the SAFA interviews.

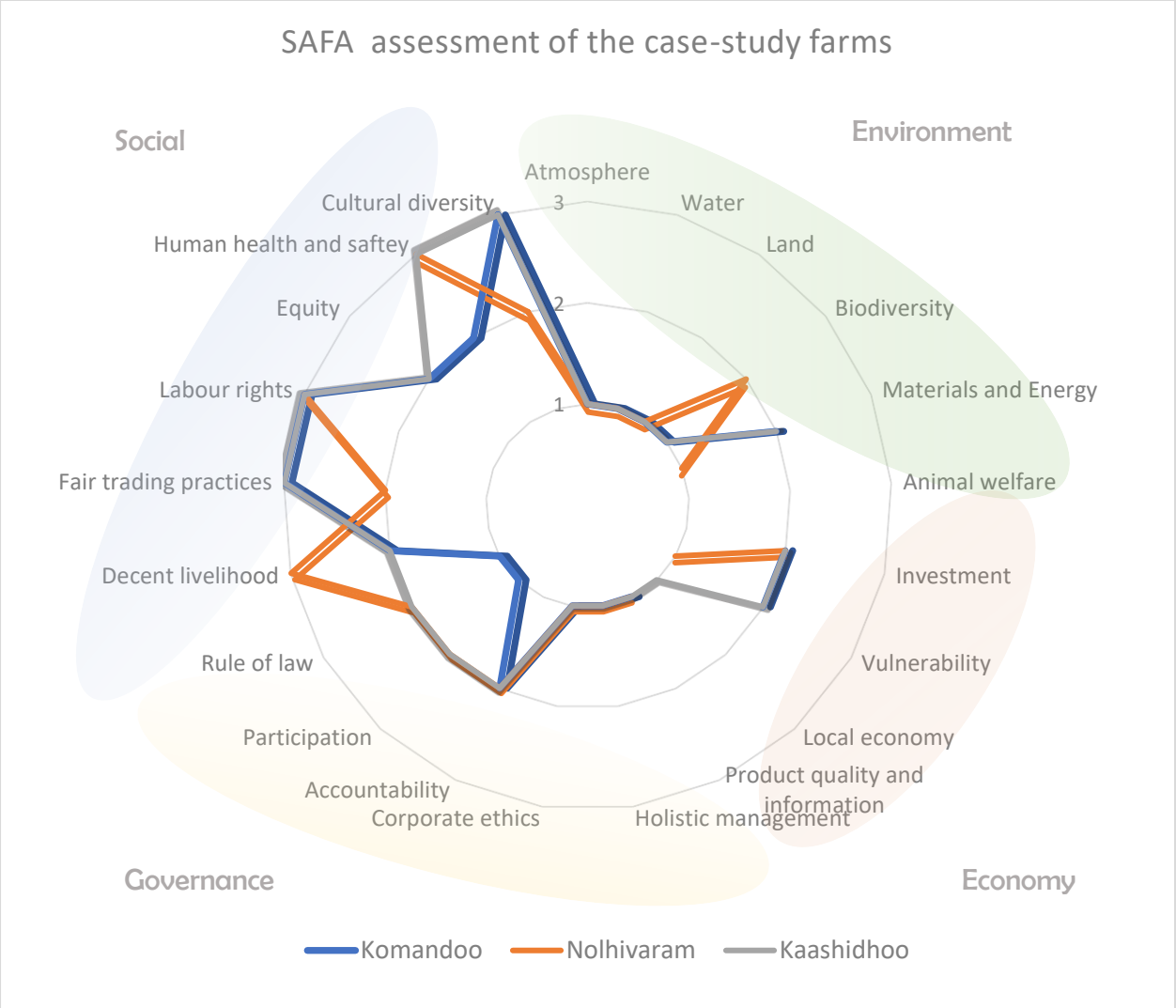


Figure 27: SAFA assessment of the case-study farm. Scales 1-3 represents performance with 1 being lowest.

# 7. Discussion

## 7.1 Environment

The case-study farms were chosen partly to compensate for the diversity of environments where production is being taking place. Each inhabited island is different in terms of the endowed resources, population, proximity to market, residential-land to community-land ratio etc. At the same time, there are defined similarities across islands in terms of soil characteristics, land management practices and climatic elements. Soil characteristics; poor soil fertility, shallow soil profile, alkaline pH, low clay content and low organic matter has been a huge challenge for farming. These factors have defined the base level for agriculture by making soil inconducive for growing diverse crops.

The challenges of land and soil are exacerbated by increased application of synthetic fertilizers as the soils are prone to leaching. Due to the high input use and current methods used in application under improper guidance, there is likely to have high wastage from leaching, seepage and nitrification (Herzong and Konrad 1992). This activity can attribute to change in the ecological environment of the farming system. Intensive studies needed to be carried out on the water and soil quality of main agricultural islands such as Kaashidhoo and Nolhivaram. Better farm planning, enhance tree integration, building biological fences, establishing borders between plots, fixed plot allocation must be considered to address these issues.

## 7.2 Ecological subsystem

There is low diversity in autotrophic, heterotrophic and decomposing subsystems. Lack of crop diversity can have negative effects in the farming system in terms of poor nutrient circulation in soil and nutrient leaching, due to high number of shallow rooted varieties. Predominant use of non-environment specific varieties (imported hybrid crops) increase the pressure for farmer and to the environment. These varieties are expected to be less resilient in extreme climatic conditions such as strong wind and flooding (Velmurugan et al, 2016). Alternatively, in the last few years, MoFA has been promoting new crop varieties such as strawberries, grapes and dragon fruits as a mean to diversify farm environment. While this may help with intercropping and mixed cropping practices it is still strengthening the dependency on foreign varieties since these crops are not found in the country. Obtaining local productive varieties might be challenging since many of earlier open pollinated crop varieties have been lost through time. However, a country-wide effort might salvage some crops that could be substituted for current popular commercial crop varieties. Also, farmers must be encouraged to use these crops for ecosystem sustainability by trading-off a portion of productivity. Market diversification and farmer-to-farmer collaboration at island level in terms of what to grow are possible ways to bring more diversity.

Islands ecosystems has been diluted with various organisms that are foreign but have become successfully naturalized and labelled as pests and diseases. It can be argued that much of the pest

and disease prevalence reported by farmers can be directly attributed to the use of imported manure, compost and seeds. Since naturalized pest is likely to become invasive in the absence of natural enemies. However, in-depth research is needed to understand this. Apart from that, several native species, which have been part of the ecosystem for a long time such as bats, crabs and birds have been dealt as introduced pests. It is important to note that once a species is labelled as 'pest' or nuisance it would be difficult to integrate it in to the system. Farmers lack experience in practicing farming in mutual presence of multiple species in terms of livestock integration and allowing pests until threshold level.

The main reasons for lack of livestock use are rooted in ecology where, there had been no report of indigenous ruminant livestock species presence in the islands, except for local breeds of poultry; chicken, ducks, geese and fowl (World Bank, 1980). On the other hand, several obstacles including lack of pasture land, availability of suitable pasture species and lack of traditional knowledge in animal husbandry makes it a big challenge for maintaining newly introduced species. More recent barriers for the farmers has been the expansion of urban areas near farmlands restricting animal husbandry activities due to health reasons (air and noise pollution, etc). For these reasons, advocation on behalf of diversity and integration is vital. For this, promoting the reintegration of traditional livestock elements such as poultry species is necessary. They may help in reducing insect pests and enriching soil.

In this endeavour, it is also important to change the focus to achieving long-term results. Many practices such as field burning, using readymade synthetic fertilizers and manures and buying seeds, instead of propagation is part of opting for quick results. Therefore, it is important to find ways to disincentivize these practices. According to Colomb et al. (2013), stockless system while not as productive can also be a successful production system. Livestock are also not completely necessary to fulfil the plant nutrient requirement and also makes it easier in achieving environmental conservation goals.

## 7.3 Management subsystem

Most farmers have made an active choice to pursue agriculture as part of their daily livelihood. Since, farmers are not forced in to it for subsistence, other motivational factors such as community status, active lifestyle and family involvement are keeping them in farming despite the challenges. This culture acts partly as encouragement for older generation to the farming activity.

Lack of technical and ecological knowledge has a strong role to play in shaping the existing practices. This has resulted in, strong reliance on ready-made products for solutions, poor application methods, excessive fertilizer use, and reduced innovation capacities. Correct knowledge is also crucial to minimize some of the disruptive practices such as, subsurface fertilizing, synthetic fertilizer mixing, excessive fertigation and application of hydroponics fertilizer for crops in soil etc. It may be important to note that although farmers do not actively identify nutrient management issues, it is masked within pest and disease issues. As several farmers

identified both nutrient deficiencies and nutrient toxicity as diseases. Misdiagnosing of nutrient related issues can be attributed to the excessive use of fertilizers. Advisory services and extension packages could be improved in this respect, formulating programs taking into account unique ecosystem of the islands, capabilities and needs of farmers with focus in utilizing local resources for recurrent problems.

Current approach to crop rotations and intercropping practices may need to be viewed from a different angle instead of a mean to reduce pest and disease issues. It could also be noted that current intercropping and mixed cropping practices are done without proper basis and thereby its potential beneficial impact to the environment is reduced. Despite the small size of farms, long-term cropping plan could be useful to integrate crop rotation and intercropping as a regular practice. alternative practices with an integrated approach must be encouraged for nutrient management. Improving current practices of mulching, legume incorporation, green manuring and above all, composting. From the group discussions, it was understood that farmers increasingly favour quick returns and the work of composting does not comply with that notion. According to Table 5, multiple factors including government involvement and youth participation has been suggested as positive changes to encourage composting. It can also be inferred from the suggested solutions that multiple solutions need to be adopted in addressing alternative practices.

Table 5: Farmer-identified challenges and solutions in relations to composting at farms

| **Synthesis of group discussion on composting** | |
|---|---|
| **Challenges** | **Suggested solutions** |
| Time consuming and hard work | Need to facilitate ways for largescale compost making and facilitate ways for getting appropriate machinery |
| Lack of youth interest in farming and lack of knowledge | Developing specific skills relating to compost making among farmers and youth |
| Not sure about the quality compare to readily available fertilizers | Promoting standard compost making process |
| No direct economic incentive | Making compulsory for resorts to buy a portion of the produce |
| Plenty of high quality fertilizers readily available | Interest free credit facilities for compost making and regulating compostable materials at island level |

Opportunities for innovation are plenty in island environment such as reducing use of external inputs, improving nutrient recycling at farm and island level. According to Davide et al, (2015), the main determinant of adopting sustainable farming practices is the past experience with such practices and in the absence of that, it is the incentives provided by responsible authorities (such as MoFA) that is the next most important factor in changing farmers habits.

Current practices on the work allocation of labourers has important implications for farming practices of the country as a whole. For instance, while foreign workers are in-charge of day to day routine such as nutrient application they have not been part of any technical training. And since, farmers themselves do not possess sufficient technical training to teach employees, this leads to question the enforcement of quality standards, judicial and efficient use of inputs. Moreover, this way of working is supporting the views of the society that farming is merely all menial work. Building trust in the locally produced food can be challenging and current practices may not aid in attracting young people to farming. According to MoFA, they are working on a way to incorporate foreign workers in their training program, but it is likely to take a long time.

Additionally, the short cut methods used in achieving high productivity is another factor, which leads to excessive use of fertilizers. Currently there are more incentives for high production. Input based subsidies and increased focus on providing cheap inputs are partial reason for this. Another reason for sole productivity focus is the use of prices of imported food as a reference to judge the price of local products. New market option could be explored for local products to separate from imported products. In this respect, more efforts on standardisation or certification of products could help making connections with tourism sector for higher price

## 7.4 Perturbations

Adopting climate smart agricultural practices can help mitigate climate related issues in the future. This means designing resilient farms with climate and environment specific crops and maximizing local resource for nutrients.

Farming culture is changing in Maldives. For instance, traditionally farming was a whole-family activity, while currently it is practiced as part-time work by family members who remained in the islands (children moved out to the cities for work or higher education). High average age of farmers and main farming purpose being an alternative low risk income source has become one of the defining factor of agriculture in inhabited islands. Older farmers (age above 55) tend to take agricultural work as more leisure activity, and therefore, suboptimal practices that give stable short-term results are adopted. Changing to a new practice (for example; reduction in fertilizer use with local compost) would be perceived as risky and older farmers tend to be more risk averse than risk takers (Cole, et al 2008). Also, older farmers in Maldives tend to have older children who are usually engaged in other profession outside residential island. Integrated nutrient management practices require long-term planning that involve analysis of the existing soil, identify nutrient requirement, schedule application methods and proper record keeping, which old age farmers might not have time/interest for.

While there is high need for involvement of younger generation, there are very few cultural drivers for this. For instance, there is no direct agricultural education in the formal curriculum from primary to higher education. Apart from that, lack of job opportunities due to the homogenous nature of agri-business discourages most youths. Therefore, youth-focused agricultural awareness programs may be important to carry out in schools and higher educational institutions.

Unstable political situation can add to the existing challenges. Government involvement is crucial for changing the direction of current farming practices. Small improvements such as change in the advisory programs, with focus on sustainable agriculture could be a good starting point. Also, building trust between farmers and advisors for agriculture knowledge may be necessary for quality, reliable and unambiguous knowledge transfer. Certification standards and other changes that require legislation may take long term in making in to practice. Also, growing societal awareness on healthy food and environmental conservation might help for the long term. However, strengthening and standardisation of land tenure system could be taken as a priority issue. Currently tenure system is oriented in a way where farmers have less incentive to care for the land. A method to make producers accountable for the work in assigned land need to be in place.

## 7.5 SAFA assessment

The overall better performance in social dimension in all three farms is likely because agriculture is not the primary means of income for the household. Inhabited islands have sufficient level of infrastructure for health, education and access to food. In this respect islands closer to capital city would fare better due to ease of access to infrastructure, food, health and markets such is the case for Kaashidhoo compare to other two islands. SAFA considered several additional areas such as waste disposal, sustainability gaols, species conservation practices and water conservation practices in its analysis. The lack of these practices combined with the poor farming practices is represented in the overall result of environmental dimension stressing on the need for alternative practices. The relatively lower performance in governance dimension indicates the loose structure of current tenure system, poor consolidation of farming work and lack of record keeping among farmers. To get a complete assessment more effort need to be put in evaluating the economic dimension. This include in-depth analysis of farm out puts and details of financial situation as currently this information are lacking due to poor management.

# 8. Suggestions

The following suggestions may encompass whole farm operation including planning, execution and record keeping. They are based on the five levels of Gliesmann scale for food system change for sustainability. All five levels taken together can serve as a roadmap that outlines in an almost stepwise manner a process for transforming the entire global food system (Gliessman, 2015). The levels are stated as follows.

Level 1. Increase the efficiency of industrial and conventional practices in order to reduce the use and consumption of costly, scarce or environmentally damaging inputs.
Level 2. Substitute alternative practices for industrial/conventional inputs and practices
Level 3. Redesign the agroecosystem so that it functions on the basis of a new set of ecological processes.
Level 4. Re-establish a more direct connection between those who grow our food and those who consume it.
Level 5. Build a new global food system, based on equity, participation, democracy, and

justice, that is not only sustainable but helps restore and protects earth's life support systems upon which we all depend.

The suggestions in this study are based on level 1 and 2 of the scale. This is because from the study it is understood that farming practices are at 'conventional' level in the region and therefore suggestion must reflect on gradual improvement. For optimum results it is advised to follow level 1 before considering level 2. Although these 'levels' are primarily aimed at farm level changes, possible actions/activities for island level improvements are also suggested. This is because island level actions are expected to influence and expedite farm level activities and also improve collaboration of island councils with farming communities in each island. In this respect island council members are viewed as actors of the system similar to farmers and suggestions for island level changes reflect on their current convention and change or substitution to those practices would contribute to farmers efforts and consequently, whole system sustainability. The farm activities when improved and substituted for better practices is expected to positively affect the hotspots described in the analysis and SAFA assessment.

The following suggestion/recommendation are based on Gliessman scale level 1 which sates:

*Increase the efficiency of industrial and conventional practices in order to reduce the use and consumption of costly, scarce or environmentally damaging inputs*.

Land leasing and allocation regulation can be improved at council level to allocate fixed plots and registration to individuals rather than household. Preferences can be given to women or person most active from the household. Also, some level of tenure fee/rent can be adopted in a standard manner.

Councils could also improve on current guidelines (or new guidelines on islands with none) advising farmers based on statistics from MoFA on water use, fertilizer management and soil management practices. For instance, recommendations could be made on maximum quantity of imported manure (in kg) to use in a specified land area, minimum number of perennial trees to be kept in a specified area, designated composting pit as part of each farm.

Similarly, at island level community waste management activities can be adjusted to provide the raw materials for composting. For instance, separate collection area can be established near major farming land for residents to leave perishable materials. More specifically, if resources permit, a community composting centre could be established for the farming community.

At farm level, farmers could Consult an extension officer from MoFA or refer to extension materials on information about soil and land characteristics, information on specific crop before purchasing inputs and commencing cultivation. Additionally, information could be obtained on specific recommended agronomy practices for selected crops at crucial stages of the crop life cycle.

At farm level, farmers could identify crop yield potential based on history of soil productivity in relation to cultivated crops (for example; estimate of how much in weight or number is expected

from each crop from experience or extension materials). Based on this and the history of the crop, estimation can be made on plant nutrient requirement. The estimates can be plot or crop specific (for example how many bags of fertilizer A or how many bottles of fertilizer B is needed based on the estimate etc..).

Farmers could determine the type of fertilizers and manure to be applied making specific note to avoid similar fertilizers (consider previous season performance, price, transport cost, availability etc). Based on these information fertilizer application schedule or plan could be formulated with specific application methods. It is important to avoid practices such as routine fertigation for crops in soil, synthetic fertilizer mixing with subsoil, fertilizer mixing without consulting a field officer. Also, if field burning is carried out, seek information on optimum ways of utilizing ash.

At farm level, after cultivation it is important to monitor plants on regular intervals and making necessary changes (arising from nutrient deficiencies or weather changes such as heavy rain periods) to the nutrient management schedule.

The following suggestions are based on Gliessman scale level 2 on food systems change for sustainability which states:

*Substitute alternative practices for industrial/conventional inputs and practices.*

Island level programs can be carried out focusing on enhancing farmer community collaborations. It could be periodical meetings (monthly or yearly), field days, community events like harvest celebrations organized by island council. These programs could include discussion on what can be cultivated, coordinated pest and disease control activities aiming to diversity methods among farmers, coordination on transportation and marketing activities. Additionally, some form or rewarding system can be arranged to recognize farmers who are practicing environmentally friendly methods.

Island council with the help of island community and island school could carry out programs such as gardening competitions, excursion trips, field work on farms as part of practical education focusing on youth and school students to promote their interests towards agriculture related work.

At farm level, farmers can consult MoFA officials or refer to extension materials on composting methods and its general application practices, integrated nutrient management practices at farm level (legumes, green manuring methods, minimum tillage, crop rotations, intercropping etc) before commencing cultivation. Also, information can be obtained on natural/organic fertilizers that are available on the market. Moreover, farmers can seek help from MoFA when designing farm for better nutrient management (ex: incorporate trees with vegetable crops, border crops, catch crops).

Furthermore, famers could identify opportunities for integrated nutrient methods at farm during the planning process. This can be achieved by substituting existing practices for alternatives or by adopting new practices in the plan. For instance, mulching, legumes, crop rotations or composting

can be included if it has been absent among practices. Similarly, if the practice has been to discard plant refuse out of the farm, it could be used for either mulching or composting.

Also, decide on a rough target level to supplement compost and how much is required. For this, it is important to identify available resources for compost making and working out a way for maintaining supply throughout cropping period such as establishing contact with supplier for locally prepared compost.

Moreover, it is important to consult with an extension officer and monitor plants on regular intervals on continuous basis during cropping period. Apart from that it would be beneficial to keep record of farm activities including fertilizing schedule and fertilizer details throughout so that this information could be used for the plan in subsequent season.

# 9. Concluding remarks

Historically, until 1980' agriculture sector in the Maldives had persisted without much dependency on foreign-sourced input and technological intervention. The agricultural system in those times were related to subsistence farming using local crops and livestock. Individual island communities were able to manage food and nutritional demands for the households.

Presently, imported rice, wheat, sugar has replaced traditional staples (such as Taro, breadfruit, millet) along with most other foods. Currently, despite the heavy dependency on foreign-sourced agricultural inputs that is created through conventional practices, the sectoral contribution to the economy has been on the decline. Practices at farm level may be described as inefficient and homogenous. Input uses have become excessive without recourse to proper application methods. Most noticeably, for an average farm, a large portion of money goes to obtaining fertilizers and manure. On a broader level, lack of knowledge, aging farming population and the motivation for farming along with poor agricultural policies could be argued as the main shaping factors of current farming system. On a closer level to farming community, the abundance of agricultural inputs, the single focus on productivity, poor coordination on farm management and land tenure system could be considered as the main contributing factors.

The practices at farm level must be improved to alleviate the pressure on natural and economic environment. In this respect it is important to draw up on the traditional farming methods such as including traditional livestock and crops and use of local resources for farm nutrients. Maldives should consider its unique situation, for example the type and size of cropping system possible, geographical isolation, limitation induced by land and soil characteristics, access to local inputs and markets in envisioning plans for the agriculture sector. There is huge potential to change current nutrient management practices at farm or island level that would impact on the farming system of the whole region paving way towards agroecological farming.

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# 11. **Appendices**

Appendix 1: Group discussion guide

Group discussion guide

My role as a facilitator:

- Introduce the goal of group discussions and purpose of study in each island
- Introduce agenda and topic/s of the day in each session
- Take notes of date, time, participants number
- Select appropriate tools to use in sessions depending on topic (brainstorming, rich picture, ranking etc.)
- Allow all participants to share ideas and take notes

Preliminary topics:

- Reasons/need for using fertilizers,
- Detail use of selected fertilizer use in farm and household (separate for organic and synthetic),
- Mapping fertilizer transport from source to farm
- Ways of nutrient movement in and out of the farm environment
- Differences of cropping practices in the past and present,
- Scenario on starting budget for a hypothetical farm
- Challenges of on-farm or island level compost making for nutrient management and the solutions to overcome those issues
- Existing situation of livestock use in farms and the solutions for improvement

General agenda for each session: Total time 90 – 120 minutes

- Introduce the topic and program of the session 5-10 min
- Within group discussion and brainstorming for 15-20 min
- Break for some refreshment 5-10 min
- Groups to share main ideas through written flipchart to all participants 20-30 min
- Open discussion between all participants to comment main ideas 10 – 15 min

Appendix 2: Key findings of group discussions

Table 6. Key points from the group discussions at case-study islands of Nolhivaram and Komandoo.

| Topic | Key points |
|---|---|
| Mapping fertilizer transport from source to farm | Farmers identify the route of fertilizer with 6-7 steps from source to farm. The source usually involves Srilanka and India. Significant portion of synthetic fertilizer is also used in the pit or planting bed preparation phase. Fertilizer use spread through the crop period irrespective of actual requirement. |
| Reasons/need for using fertilizers | Farmers identify the fertilizer use equally important for all plant needs including disease prevention and control. |
| Detail use of a selected fertilizer in farm and household (separate for natural and synthetic) | Continuous application is preferred for desired outcome. Key application times are identified in a way each fertilizer can be fully utilized by the end of crop cycle. |
| Ways of nutrient movement in and out of the farm environment. | Farmers needed help in conceptualizing this. Main mean out of farm are through plant harvest. Farmers do not consider field burning as a mean of nutrient loss. Not knowledgeable in the concept of composting. |
| Differences of cropping practices in the past and present | Farmer recognize having more species diversity in the past. For example, there was some level of grains such as millet, maize and lot more root vegetables such as cassava. In the nutrient management lot of ash and dry leaves were directly mixed with soil during tilling. Lot of fish and coconut plant based elements were used as fertilizers such as fish bones, remains of fish processing and decomposing coconut wood. |
| Scenario on starting budget for a hypothetical farm | Participants allocate around 30 - 40%% of the farm expenditure as fertilizer cost and manure. Manure cost includes about 60-70% of this amount. |
| Challenges of on-farm or island level compost making for nutrient management and the solutions to overcome those issues | CHALLENGES: Time consuming, lack of knowledge. Not sure about the quality of compost compare to readily available fertilizers. Not direct economic incentive. Plenty of high quality fertilizers readily available. Lack of youth interest in farming.<br><br>SUGGESTIONS: More information dissemination, Need to facilitate ways for largescale compost making, making compulsory for resorts to buy a portion of the produce. Developing specific skills relating to compost making among farmers and youth. Facilities ways for getting appropriate machinery. Interest free credit facilities for compost making. Plan ahead in designing and managing farm. |
| Existing situation of livestock use in farms and the solutions for improvement | CHALLENGES: lack of awareness. lack of knowledge of animal husbandry and especially nutrition and diseases. Poor of financial incentive, Not enough land, Animal husbandry is high risk enterprise, Unavailability of good livestock breeds<br><br>SUGGESTIONS: Restrictions in having animals near residential areas, specialized programs on animal husbandry, allocating uninhabited islands for animal rearing, Interest free credit scheme, veterinary service and specialized skilled personnel |

Appendix 3: Interview questionnaire

Semi-structured interview questionnaire

1. General information Name: Form no: Date: Location

   a. Age
   b. Gender
      Female
      Male
      Prefer not to say
   c. What is the size of your farm?
   d. What is your role in the farm business?
      Owner
      Other (specify)
   e. How long have you been involved in farming?
   f. Besides you, who are the people working in the farm enterprise?
      Spouse
      Hired labor (temporary)
      Hired labor (full time)
      Children
      Other (specify)
   g. Is the farming the sole mean of family income?
      Yes
      Yes but children support
      No
   h. What are the main crops grown in the farm?
   i. Which crops and how much of the harvest are used for home consumption?
      Less than 10% Between 10 - 25%- Between 25 - 50% More than 50%
      (crop name)

2. Farming knowledge
   a. How did you learn farming and what is the source of your main farming knowledge?
      Parents/grand parents
      Neighbors / other farmers
      Formal training (less than 3 months)
      Formal training (more than 3 months)
      Self taught
      Other (specify
   b. How would you describe your current farm system?
      Unchanged from traditional farms / organic by default
      Organic
      Conventional
      Other (specify)
   c. Have you heard of organic farming or any other alternative to conventional methods?
      Yes

Maybe but not sure
No, I have never heard of it.

d. If yes, then how would you differentiate it from your current practices?
e. What would be your ideal farm or model farm? please describe it in terms of types of crop, size, location etc.)
f. Do you keep record of farming activities? If yes please elaborate.

3. Issues and opinions
   a. What are your main challenges and in your opinion, what are the key issues faced by other farmers in your island or neighborhood?
   b. Generally speaking, do you think it has become easier or challenging to practice agriculture in present times? And why?
   c. What practices can you identify as recently adopted compare to or is different from when you started?
   d. What are the main inputs purchased for your farm on seasonal basis?
      Seeds
      Fertilizers/compost/soil amendments (organic and chemical)
      Pesticides
      Other
   e. Please place a break down estimate of seasonal input cost for in relation to total seasonal expenditure (percentage)
      Seeds
      Fertilizers/compost/manure (organic and chemical)
      Pesticides
      Other
   f. Do you believe you can practice farming by using inputs (seeds, pesticides, fertilizers and soil amendments) that are sourced from the island or in Maldives in general? and why?
   g. Please, list possible locally available substitutes for the imported inputs that you can use in the farm?
   h. What would the prediction for the future of your farm business in the next 10 years in terms of the following factors?

      0 (will decline) to 3 (Improve significantly)

      Productivity
      Economic return
      Cost of input
      Local resource use

4. Farm nutrient management
   a. What are your main issues in relation to crop nutrition?
      Diagnosing and managing nutrient deficiencies
      Limitations in getting appropriate fertilizer
      Knowledge on fertilizer application methods
      Other (specify)
   b. What are the most limiting nutrient(s)in your farm?
      Nitrogen (N)

Phosphorus (P)
Potassium (K)
Iron (Fe)
Magnesium (Mg)
Other (specify)

c. Which phase of the production cycle takes up most of the fertilizer?
   Land or bed preparation phase
   Growth phase before flowering or fruiting
   Late growing or maturity phase
d. What are the main crops grown in the farm that has the highest nutritional need? (list in the order of importance).
e. Do you have livestock in the farm? if so what kind of livestock and what is the density?
f. Please tick the box(s) if you employ the following practices?
   Green manuring
   Legumes
   Composting
   Fertigation (nutrient is supplied during irrigation)
   Application of on-farm nutrient (household waste, kitchen refuse, etc..)
   Animal manure
g. If you grow legumes, please elaborate on the process and uses? (types of crop, methods of planting, proportion of the field etc...)
h. Do you follow a nutrient management plan or fertilizer application schedule?
i. If yes, then can you elaborate the process and key factors involved?
j. Can you list the main fertilizers used in the farm in a single season?
k. What are the key factors that influence your choice of fertilizers or nutrient sources? Rank: 1 most important, 5 least important.

| | Rank between 1 to 5 |
|---|---|
| Price | |
| Cost of transportation and application | |
| Effectiveness | |
| Popularity among farmers | |
| Availability and accessibility | |

l. Do you carry out any form of composting at farm level? If Yes, can you elaborate the process and its application?
m. Can you estimate what proportion of total fertilizer input is currently sourced from the locally available material?
n. How often do you consult with nutritional expert on matters relating to nutrient management? And who do you consult for advisory services?
o. Do you carry out soil testing for nutrient content? If so, can you elaborate the process?

Appendix: 4 Stakeholder interview guide

Stakeholder interview

Name: Survey no:
Role/position/profession: time and place:
Period of involvement: Date:

1. How would you describe the progress of agriculture sector over the years?
2. Is the direction of the progress sustainable? Give reason for your answer?
3. In your opinion, what are the main issues in the current agriculture system?
4. What needs to be changed to alleviate these issues?

   For private sector
   Public sector
5. What is your opinion on the input use in current farming practices?
6. In general how has the farming system changed last 25 or so years in terms of?

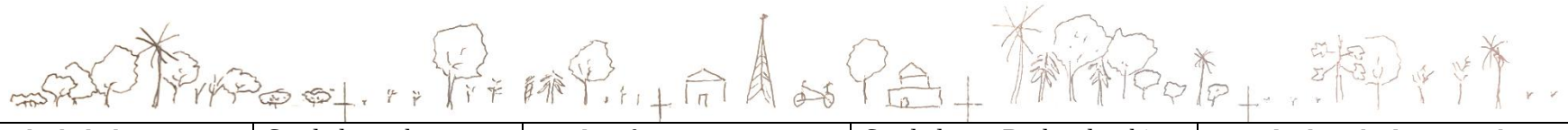
   Number of farming business/families?
   Average farm size?
   Average operational cost?
   Overall risk level?
   Input requirement?
   Crop diversity?
7. Are there political barriers for change and what immediate policy changes are needed?
8. What factors are most in need of improvement in advisory system?
9. Who should have a the most active role in advisory services, and why?
   - Trained professional extension officers?
   - Farmers?
   - Agri-input suppliers or businesses ?
10. What can be done to improve the local resource use in farms?
11. What can be done to improve the nutrient management at farm or island level?

Appendix 5: Transect walks carried out in case-study farm islands (Table 7 – 9)

Table 7 : Transect walk carried out in Mathikomandoo island

| Length of transect from the starting | 0-16m | 16-30m | 30-45m | 45-121m | 121-250m |
|---|---|---|---|---|---|
| Soil + Land | Coarse gravel with sand | Coarse grey sad, Well drained | Dark fine sand | Sandy loam, heavily tilled | Dark grey, rich OM , fine sand |
| Vegetation+ Crops | Salt tolerant shrubs (pandanus, Sea lettuce) | Shrubs, tall weeds (Beach sunflower, wild gooseberry, Noni) | Native perennial woody, plants and weeds (Indian tulip, Seabiscus) | Early stage watermelon, Foreign verities | Dense vegetation with shrubs and perennials (Coconut, fish kiler tree, Wild pandanus, *Ficus sp*, Indian almond) |
| Materials | Stands for drying fish | (Only vegetation) | Resting hut and storage, Chair table, Well for fresh water | Fence, Wheelbarrow, Farm tools, Waste products | Some plastic rubbish |
| Thoughts with respect to study | Not good for salting fish, too hot, More people need to utilize these resources | Need more trees, Better planning needed, More community involvement needed | Essential utilities needed, living too close to farms, Need more cleaning | Nice even land, Shouldn't burn the field, Top soil too disturbed, Better farm design needed | Good for relaxing, Coconut stock getting old, Nicely regulating natural system |
| Water source | Ground water and rain water | | | | |
| Land cover | 60-70% | 85-90% | 50% | 10% | 90-95% |
| Difficulties | Difficult to access in bad weather | Salt intrusion in ground water | Far from residential areas, No electricity, Salt spray | Too close to each other, Not enough border between plots | No policy to use natural vegetation, Has bats, Crows and mice as pests |
| Opportunities | Harbor area can be developed | Access roads, can plant useful trees, Can grow fodder | Can use local resource for building, Opportunity to rear livestock | Could make better use of native trees, need long term, Lot of materials for composting | Good natural defense from weather and salt spray, Diverse flora, rich soil |
| Socioeconomic indicators and livestock | UNINHABITED ISLAND | | | | |

Table 8: Transect walk carried out in Kaashidhoo island



| | | | | | |
|---|---|---|---|---|---|
| Soil + Land | Thick dark grey, Lot of organic matter | Sandy loam, heavy disturbance in plots | Hard surface, uneven in some places | Sandy loam, Dark color, bit moist | Heavily disturbed, not much weeds, Sand and dry, Bare in most parts |
| Land cover | 80% | 20% | 10% | 75% | 25% |
| Vegetation+ Crops + livestock | Native vegetation, Perennials and shrubs | Diverse crops, No livestock, Vegies, herbs, fruits | Fruit trees in the home gardens, Shade trees in the center of the road | Diverse native area, coconut and large perennials, Lots of undergrowth | Heavily cultivated crops, Passion fruits for fences, Banana as border between plots, Watermelon, Naaga, cucumber, papaya, betel leaf |
| Materials + socioeconomic elements | Not much rubbish, waste collection place, Some traditional resting area | Lots of Cow dung bags, Nets, huts for petrol pump, Irrigation lines in some farms | School, Mobile network, Mosque, houses, Motorbikes, Island office | No rubbish, Wheel burrow | Drying sheets for Cow dung, Foreign workers, Farm tools , Irrigation pipe lines, Farmers |
| Thoughts with respect to study | Big island for Maldives, Diverse vegetation | Big plots, Experienced farmers, \|Cultural roots to farming, Uses latest materials | Clean households, People love plants, Most people has land | Current practices could be harmful, Lots of trees and shade | Diverse crop, Inputs, easily available not enough care for the land, Farmers are more individualistic |
| Difficulties and challenges | Too warm in dry season, Lot of invasive species | Lot of diseases, Low fertility in soil, Expensive inputs, Heavy reliance on inputs | Residence moving to Male', No banking facility | No forestry plan, Farming threatens natural ecosystem | Old land allocation system, No young people involved, Unsafe ground water maybe, Poor collaboration between farmers |
| Opportunities | Develop for multifunctionality, Expand waste management | On-farm composting, Integrated pest management, Different farming techniques | Awareness programs to attract youth, Need banking facility | Agricultural education, Sources of material for composting | Establish links with waste management for composting, Better farm design, Farm resource management. |

Table 9: Transect walk carried out in Nolhivaram island

| Nolhivaram | | | | | | |
|---|---|---|---|---|---|---|
| Length of transect From starting point | 0-150 (150)m | 150-450 (300)m | 450 – 670 (220)m | 670 – 900 (230)m | 900 – 1100 (200)m | 1100 – 1250 (150)m |
| Soil | White to grey sand, Fewer organic matter, Maybe 0.5 to 1m deep | Dar grey sandy soil, Maybe sandy loam, Well drained, Fences, Nursery items, Empty cow dung bags | Gravel on top soil, Heavy disturbance, Dark grey soil, Uneven ground | Hard sandy pan, No top soil, Some place dug for sewerage system, Standing water | Dark grey, Lot of organic matter, Moist in places | Soft fine sand, Dark grey, Muddy in some places |
| Vegetation + Crops + Livestock | Native bushes, few trees, Salt tolerant varieties, Few coconut plants | Some hedge plants, Imported crop varieties (Some native (pumpkin, sponge gourd passion fruit) | Newly planted banana, Cleared undergrowth, Coconut grooves, Local timber species | Some fruit plants (wax apple, custard apple), Betel leave grooves, Cork woods, Hibiscus, Passion fruit, Pop wine | Dense vegetation, Some local papaya, Tall weeds, local bushes and perennials, Coconut, Indian almond | Various mangroves species, Mainly random |
| Materials | Some single use plastic, Rubbish (not separated) | Huts, Wheelbarrow, Rubbish, household items, Farm implements (no machinery) | Rubbish on the roadside, 'Joali' for sitting | Expensive motorbike, Rubbish on the roadside, Kids playing on the street, Local shops on the side | Narrow work way, Lot of vegetation, Local birds, Rubbish | Rubbish, Logs to prevent over flowing |
| Land cover | 80% | 10% | 30% | 20% | 80% | 85% |
| Other observations | Proper coastal management | Farm too close by, No organization in the farms | Need street lights, too much natural Habitat cleared, | Bad roads, Kids riding motorbike, Poor waste management | Nice and dense vegetation | No control on field burning |
| Difficulties | Invasive plant species present, Unorganized natural area | Possible soil contamination, Variety of diseases and pests, No electricity | Un management planting, Deforestation, Poor roads | Poor awareness on waste handling | Poor access, Poor planning, | Salt water intrusion, Rubbish in the pond, Development needed |
| Opportunities | Can be developed as nice access area | Farm collaboration would be beneficial, compost making, livestock | Better use of native trees, Policy for land clearing | Better housing plan, Better road development | Ecological education for school children, Expansion for agriculture | Can make designated protected area, Fresh water source |