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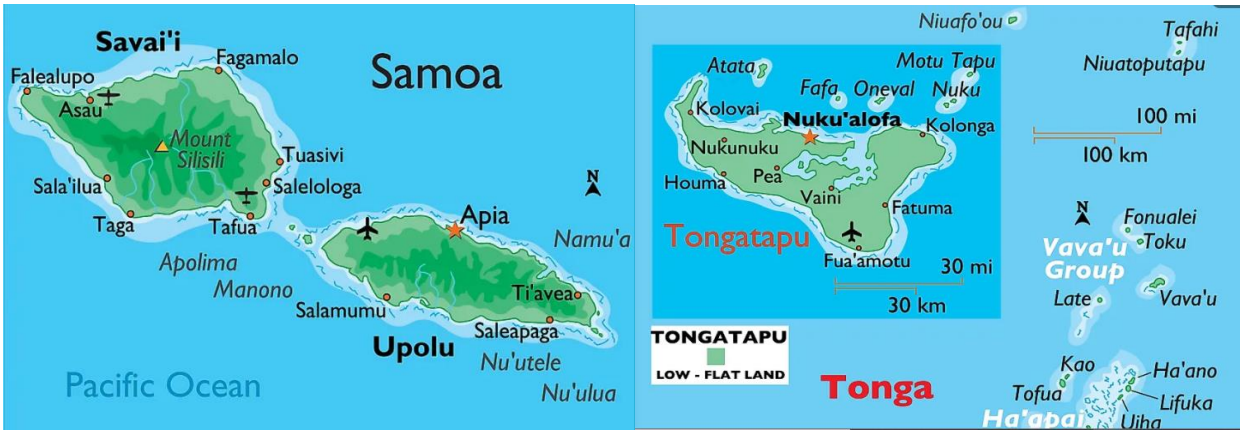
‘Strengthening the rationale on the nexus of biodiversity-climate change-food and nutrition security in the Small Island Developing States (SIDS) of Samoa and Tonga’

Literature Review



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Executive Summary

The Small Island Developing States (SIDS) in the Pacific region constitute an area of diverse nations that face the triple burden of malnutrition. The region suffers from the highest rates of non-communicable diseases and prevalence of overweight and obesity globally and at the same time registered stagnations in the prevalence of stunting, wasting and micronutrient deficiencies. Remoteness and import dependencies for food security and livestock feed, shocks, limited land for agriculture production and high exposure to the impacts of climate change confer further regional vulnerability. Therefore, building and governing a resilient and sustainable food system is at the heart of SIDS sustainable development for healthy people and ecosystems, and vibrant economies.

The region is divided into three sub-regions of, Melanesia, Micronesia and Polynesia. The latter includes the Eastern Pacific countries Samoa and Tonga, which are of focus within the current literature review. With continuous urbanization in both countries, the agricultural production per capita is declining, thus the dependence on imported foods is increasing. Hence mainstreaming biodiversity for food and agriculture is key to achieving sustainable development. However, the effectiveness of agrobiodiversity in simultaneously addressing those challenges needs cross-sectoral collaboration and integrative system approaches.

Food plays a major role in the daily life and culture in both Samoa and Tonga. Half the household expenditure is on food items and general energy intake is high in both countries, while dietary intake lacks diversity and micronutrient-rich food items. The shift from traditional diets towards more processed and imported food items is visible. For example, the intake of legumes and beans decreased while the intake of sugar-sweetened beverages increased (see **Figure 1**). This fact is not only visible on the plate, but also showing in the high prevalence of overnutrition. Almost 90% of the adult population is overweight/obese, while already around 10% of the children below five years of age are classified as overweight. At the same time, Samoa and Tonga face a low prevalence of chronic and acute malnutrition, however, micronutrient deficiencies are high. Evidence from a cross-sectional study in Samoa showed that almost 60% of children are not reaching their recommended dietary allowances, while national data shows that only 20% and 50% of children respectively in Samoa and Tonga reach minimum dietary diversity.

Current production systems follow the conventional path that maximizes yields and is highly dependent on external inputs, with simplifications leading to a loss of local diversity and soil, making the system even more vulnerable to external factors such as climate-related challenges and food insecurity. Traditionally, the islands had a deep understanding and knowledge of their environment, which is fading away. Thus, there is a need to capture and mainstream existing community knowledge and to link it with new research findings and other sectors to build a multi-sectoral approach. As the traditional farming systems in each region are different, country-specific systems need to be developed. Currently, Samoa is characterised by diverse production systems, while in Tonga the farming systems are based on non-permanent agroforestry with two-thirds utilised for root crops. Traditionally, fish plays an important role as the main source of protein in the region, but extensive fishing practices have substantially reduced fish stocks. Although many attempts have been made to introduce alternative fishing practices, fish consumption and production remains low.

The SIDS territories are extremely vulnerable to natural disasters including cyclones, floods, earthquakes, and tsunamis, which cause significant negative impacts on both socio-economic systems and natural ecosystems. The climate in Samoa and Tonga as well as in most of the Pacific region is affected by large-scale phenomena such as the El Niño Southern Oscillation (ENSO), a major climate driver influencing temperature and rainfall patterns, and even the location of cyclones and sea-level height. In addition,

climate change poses a more complex global challenge. Climate models project a 1.5 ° C increase in global temperature over the next three decades, which in the region implies that extreme high temperatures will probably be more frequent and rain patterns more unstable and increasingly intense and frequent. The environmental and economic impacts these climatic events have on coastal and terrestrial ecosystems are already affecting people's livelihoods, particularly agriculture and fisheries, which is becoming more evident in the fragility of the conventional food systems. It follows that the need to integrate ecologically-sound management strategies to enhance climate resilience and mitigation capacities within the food system have become urgent.

In this review, we also used the text mining analysis on legal documents to identify key specific areas where cross-sector collaboration can and should be fostered for mainstreaming biodiversity for food and agriculture. In total, 27 and 23 legal documents in relation to health/diets, productions systems and other resources, such as policies, acts, national plans and regulations from Samoa and Tonga respectively were analysed to identify the legal framework and environment to enable biodiversity for food and agriculture (BFA). The search investigated three themes: BFA for production (agriculture and fisheries), BFA for food security, nutrition and health, and BFA for future use and prosperity (environment, conservation, climate resilience). Two key points common across both countries were recognised. There are gaps in multisectoral efforts for adopting BFA promoting sustainable production, diets, and future use. Hence the need for greater coordination to support organic, agroecological, and home gardens across sectors such as health, agriculture, and environment that could promote more diverse and sustainable food systems.

The food system is a very complex framework, which needs multi-sectoral thinking and collaboration. Additionally, the current food-system dynamics of the Pacific Islands are highly vulnerable to extreme events Also, there are no current multi-sectoral collaborations, which are needed for better coordination and bridging efforts towards the same goal. Through key informant interviews and focus group discussions identifying successful and potential collaborations regarding BFA will enhance the understanding of the nexus on BFA, food and nutrition security, and climate change and foster collective action for projects towards sustainable and resilient food systems.

Outline

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Abbreviations

ASGG	Agriculture Sector Growth Committee
AusAID	Australian AID
BFA	Biodiversity for Food and Agriculture
CBD	Convention on Biological Diversity
FAO	United Nations Food and Agriculture Organization
FIES	Food Insecurity experience scale
FSGG	Fisheries Sector Growth Committee
GEF	Global Environmental Facility
GDP	Gross domestic product
GHG	Greenhouse gases
GOS WB	Government of Samoa World Bank
IPM	Integrated Pest Management
ICT	Information and Communication Technologies
LUCF	Land-Use Change and Forestry
LSU	Livestock Standard Unit
MAFFF	The Ministry of Agriculture, Food, Forests and Fisheries, Tonga
MCTI	The Ministry of Commerce, Trade and Industries, Tonga
MDD	Minimum dietary diversity
MEIDECC	The Minister for Meteorology, Energy, Information, Disaster Management, Climate Change and Communications
MESCAL	Mangrove Ecosystems for Climate-Change Adaptation and Livelihoods
MMF	Minimum meal frequency
MNR LMD	The Ministry of Natural Resources and Environmental Land Management Division
MNRE	The Ministry of Natural Resources and Environment, Samoa
MoH	The Ministry of Health, Samoa/Tonga
NBSAP	Samoa's National Biodiversity Strategy and Action Plan
NCD	Non-communicable diseases
NDC	National Determined Contributions
NHS	National Health Services
NzAID	New Zealand AID
PACRES	Pacific Adaptation to Climate Change and Resilience Building project
PICT	Pacific Island Countries and Territory
RDA	Recommended dietary allowance
SBS	Samoa Bureau of Statistics
Sector ias	Sectors implementing agencies
SIDS	The Small Island Developing States
SPC	The Pacific Community
Tf	Term frequency
WFP	World Food Programme
WHO	World Health Organisation
WIBDI	Women in Business Development Incorporated
WRA	Women of reproductive age
WRI	World Resource Institute

Preface

This study has been commissioned by FAO to help strengthen the rationale on the nexus of biodiversity-climate change-food and nutrition security in the Small Island Developing States (SIDS) of Samoa and Tonga. The literature review examines food and nutrition security levels in Samoa and Tonga, in the light of biodiversity for food and agriculture (BFA), the current agricultural system, and climate-change mitigation strategies. The policy environment and landscape to mainstream BFA is also investigated. The study identifies existing gaps and opportunities and recommends the next steps to ensure the nexus of BFA, farming systems, food and nutrition security and climate-change adaptation is strengthened to dynamize livelihoods and ecosystem services.

For the target geographies of Samoa and Tonga, **Section 1** introduces the background to the study. **Section 2** investigates several components of the food system, including consumption patterns, common food sources, and the respective outcomes. Additionally, current food security levels and nutrition-related challenges in Samoa and Tonga are reviewed. **Section 3** explores the sufficiency of the current diversity within the prevalent agricultural production systems, their characteristics, and the prospect of new production systems that (could) contribute to diversity, climate-change resilience and livelihoods. **Section 4** presents an investigation of climate-change mitigation strategies and the status and use of BFA, including findings of existing research and development interventions. **Section 5** outlines the text-mining methods used for the review to determine evidence of mainstreamed BFA in policies in Samoa and Tonga. The analysis identifies specific areas for cross-sector collaboration on mainstreaming BFA. Two key common points are: i) gaps in multisectoral efforts to jointly promote sustainable production, healthy diets, and BFA for future use, and ii) policies only mention a limited number of crop and tree species. Selecting and supporting the adoption of a wide range of local or multifunctional BFA adapted to local conditions can increase the benefits of orchestrated interventions. Policies remain heavily focused on cash crops (particularly in Samoa), contributing to neglected key crop and tree varieties/species for nutrition, sustainable production, and resilient farms. Finally, **Section 6** examines the complex food systems framework, considering the nexus of food and nutrition security, climate change and BFA, and the threats it faces, while **Section 7** formulates recommendations to ensure the nexus of BFA, farming systems, food and nutrition security and climate-change adaptation is strengthened to dynamize livelihoods and ecosystem services. In **Section 8** the authors acknowledge those several actors supporting this study.

1. Introduction

The Pacific Island region is an area embracing diverse nations that currently suffer the highest rates of non-communicable diseases (NCDs) globally (Bell and Taylor 2015; Win Tin et al. 2020). NCDs, including cardiovascular diseases and diabetes, account for 70% of the premature deaths in the region (Santos et al. 2019). At the same time, stagnation in the prevalence of stunting, wasting and micronutrient deficiencies are visible, while the region encounters the fastest growing rate of overweight and obesity in the world (Blankenship et al. 2020). Thus, the region faces the triple burden of malnutrition, which is characterised as the coexistence of overnutrition (overweight and obesity) alongside undernutrition, micronutrient deficiencies or NCDs at all levels of the population (Blankenship et al. 2020; Davis et al. 2020). Additionally, the Small Island Developing States (SIDS) face high pressure to develop sustainably, while embracing their vulnerabilities. Remoteness; import dependency for both food security and livestock feed; shocks (e.g. economic, natural, pandemics); limited land for agriculture production, and high exposure to climate-change impacts render the region extremely vulnerable (McGregor et al. 2016; FAO et al. 2017; WFP and SPC 2018; Win Tin et al. 2020). Climate-change projections suggest that the region is likely to experience an increased frequency of extreme weather events (storms, floods, droughts), and an increased intensity

of cyclones. These will lead to less predictable farming conditions; loss of coastal lands due to rising sea level; increased incidence of crop and livestock pests and diseases, and livestock physiological stress due to heatwaves (McGregor et al. 2016). Through these emerging challenges and reliance on food imports, the urban population is highly vulnerable to food-price spikes, and disasters that disrupt transport routes (WFP and SPC 2018). Therefore, building and governing for resilience and adaptation is at the heart of SIDS's strategy for sustainable development for healthy people and ecosystems, and vibrant economies.

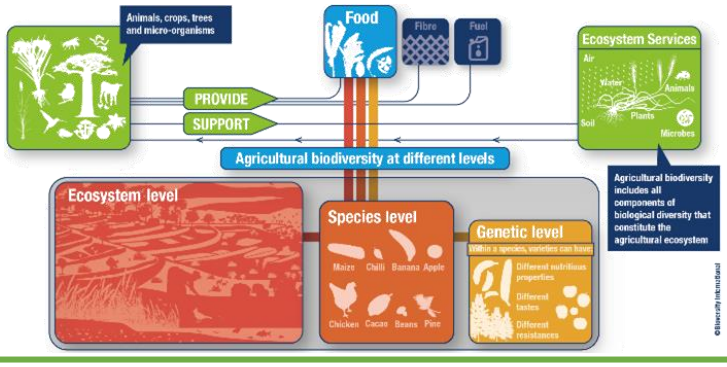
The region can be subdivided into three sub-regions, Melanesia, Micronesia and Polynesia. The latter, located in the Eastern Pacific, which includes Samoa and Tonga, is the largest group and is characterized by a small number of islands with a predominantly volcanic origin. Polynesia holds the smallest population, due to migration to Australia and New Zealand as a consequence of reduced availability of specialised labour and rural-urban migration, which is higher than the population growth rate (WFP and SPC 2018). The population growth rate of Tonga for example declined to an annual rate of -0.5%, with 23% of the population living in the three urban districts of the Kingdom (Tonga Statistics Department 2019).

With continuing urbanization, agricultural production per capita is declining. Thus, dependence on imported foods is increasing, while access to food depends on the economic ability of the household, leaving the region with sufficient dietary energy, but insufficient diversity (WFP and SPC 2018). Biodiversity loss and ecosystem services loss, as well as unhealthy diets jointly increase SIDSs vulnerability and interfere with their sustainable development (FAO et al. 2016). Mainstreaming **Biodiversity for Food and Agriculture (BFA)** – (Box 1, also called agrobiodiversity; (Hunter et al. 2017; FAO and Commission on Genetic Resources for Food and Agriculture 2019)) in the institutional development agendas, fields, and plates are key to achieving sustainable development as indicated already by a plethora of national and international organizations (Thaman 2008; Taylor et al. 2009; FAO et al. 2016, 2017; Vainikolo 2019; WHO 2020a). Nonetheless, the effectiveness of harnessing BFA for simultaneously addressing those challenges rests on **cross-sectoral** collaboration, and the use of **integrative system** approaches (FAO et al. 2016; McGregor et al. 2016; FAO et al. 2017; FAO 2019; Vainikolo 2019; WHO 2020a).

In this literature review, the focus is on the countries Samoa and Tonga, their food and nutrition security levels in the light of BFA, the current agricultural system and climate-change mitigation strategies. The policy environment and landscape to mainstream BFA is also investigated. The study identifies existing gaps and opportunities and recommends the next steps to ensure the nexus of BFA, farming systems, food

Box 1: Agrobiodiversity - *"the plants, animals and microorganisms that contribute to food and agriculture and whose diversity is the result of interactions between people and their environment over many millennia" (Hunter et al. 2017).*

Biodiversity for Food and Agriculture *(BFA) is taken to include the diversity of animals, plants and micro-organisms at the genetic, species and ecosystem levels that sustain structures, functions and processes in and around production systems and provide food and non-food agricultural products (FAO and Commission on Genetic Resources for Food and Agriculture 2019).*



and nutrition security and climate-change adaptation[1] is strengthened for better livelihoods and ecosystem services.

2. Food and nutrition security in Samoa and Tonga

This section outlines investigations of several components from the **food system**. It covers, for example, the food environment under which individual factors, including consumption patterns, common food sources, and the respective outcomes. Additionally, current food security levels and nutrition-related challenges in Samoa and Tonga have been reviewed.

a. Consumption patterns

To capture consumption patterns, food access and adequate nutrient intake, so-called dietary diversity scores are often captured and calculated at different levels, such as the household, women of reproductive age (WRA) and children below the age of two. At the individual level, the consumption of a certain number of pre-defined food groups is a proxy for adequate nutrient intake and dietary quality, while at the household level it is a measure of the economic access to food, displaying one dimension of food security (Kennedy et al. 2010; FAO and FHI 360 2016; World Health Organisation 2017). Only data of minimum dietary diversity for children under the age of two years are available, other dietary diversity indicators are currently not accessible for Samoa and Tonga. In Samoa, 20% of the children reach minimum dietary diversity (MDD), meaning they consume five or more food groups and over 45% reach minimum meal frequency (MMF) (World Health Organisation 2017; SBS et al. 2020). Over 50% (53.5%) of the children in Tonga reach MDD and 51% MMF (TSD et al. 2019; UNICEF 2019).

Food plays an important role within the Samoan and Tongan culture and life. In Tonga, over 51% of households' expenditure is on food, which is mostly spent on meat (30%), vegetables (24%), bread and cereal (>14%), (Ma'asi and Francis 2020), while the average expenditure on food in Samoa is 45%. Traditionally, the main component of the diets within the Pacific region was fish with an annual consumption of 79kg/person/year, which is a culturally and economically important element of food security (WFP and SPC 2018), although it had been decreasing. New recommendations by the Pacific Community Public Health Programme recommends 35kg/person/year to maintain good health. However, both countries have gaps in production and/or encounter difficulties in distribution (Bell et al. 2011). In recent years, consumption patterns and food preferences are shifting towards unhealthy foods like non-core food types which include confectionery, unhealthy snack food and edible ices, and processed meat (Veatupu et al. 2019). For example, in Samoa, five main food groups contribute to 80% of the average daily intake. Those five are sweets and sugar; cereal and their products; roots, tubers and plantains; pulses, seeds and nuts, and meat and meat products, restricting the diet to 13 core food items (Troubat et al. 2020). Similarly, a study published in 2019, identified bread and cereals, fresh fruit and vegetables, meat and alternatives, as well as staple vegetables as core food crops consumed in Tonga, excluding fish and seafood (Veatupu et al. 2019).

In general, caloric or energy consumption is quite high in both countries, while the diet lacks diversity and micronutrient-rich food items. In Samoa, only around 1.7% and 0.5% of female and male adults respectively between the ages of 15 to 49 years consume at least 20 servings of fruit per week (SBS et al. 2020). Thus, vitamin A intake is below the recommended average, with only 70% reaching the recommended intake level (Troubat et al. 2020). Through the intake of taro as the staple and traditional

[1] Throughout the document we use the term 'Climate-change adaptation' as a shorthand for 'to adapting to climate change and mitigating the effects of climate change'.

food item, the minimum required intake of iron (non-haem iron) is met by the population in Samoa (Troubat et al. 2020). However, overall only 14% of Samoans have access to the recommended nutrient levels (FAO and SBS). In contrast, in Tonga according to data from 2014, 73% of those aged 25 to 64 years consumed less than 5 combined servings of fruit and vegetables per day. On average the consumption was 3.9 servings, 1.8 of fruit and 2.1 of vegetables (Tekiteki et al. 2014). Other food groups such as fruits, vegetables, nuts are potentially below the consumption target values (250, 360, 60 and 20.5 gr day^{-1} respectively (see **Figure 1**) (Johns Hopkins University 2020).

Respective per capita consumption of non-starchy vegetables (Samoa 46 gr/d; Tonga 24 gr/d), beans and legumes (Samoa 187 gr/d; Tonga 112 gr/d), and unprocessed meat (Samoa 14 gr/d; Tonga 4 gr/d) decreased during the last 30 years, with a sharp increase in sugar-sweetened beverage consumption (Samoa by 16 gr/d; Tonga 24 gr/d) (see **Figure 1**). Sugar-sweetened beverage consumption exceeds the limit value at least 56 times (i.e. 2.5 gr per day), which is extremely high despite the soft drink tax and import duty on unhealthy food in Samoa and Tonga (Thow et al. 2011). In other numbers, the daily consumption of carbonated soft drinks is 54% and 56%, while 79% and 70% of Samoan and Tongan school-going adolescents (12 to 17 years of age) consume fast food[2] weekly. Both intake levels are above the world averages of 29% and 49%, respectively (WHO et al. 2017; Johns Hopkins University 2020; WHO 2020b). The prevalence of adolescents eating less than the required fruit and vegetable consumption is below the world average of 36% and 31%, with a prevalence of 31% and 38% of fruit consumption and 29% and 21% of vegetable consumption for Samoan and Tongan adolescents, respectively (Johns Hopkins University 2020). These unhealthy diets are affecting a large proportion of the population, which is one key factor in the rise of overweight and obesity in the countries.

The average fat intake in the region is on the upper limit (24%) of the recommended threshold between 15 to 30%. According to Martyn et al. (2017), the main sources are coconuts (19%), chicken pieces (13%), canned mackerel (8%) and cooking oil (6%) in Samoa (Martyn et al. 2017; Santos et al. 2019), while 65% of the daily fat intake of adults between 40-59 years of age is from imported foods in Tonga (Santos et al. 2019). The main sources of sugar are sugar, jam, honey, chocolate and confectionery in Samoa, and sugar and confectionery in Tonga (Santos et al. 2019). According to 24h-urine data in Samoa, adults have an average intake of 7.1 g/d of salt from table salt (39%), instant noodles (9%) and canned mackerel (9%). The average salt intake in Tonga is lower at 6.9 g/d (Santos et al. 2019), compared with a recommended daily intake of less than 5g of salt(WHO 2021).

[2]Fast food is defined according to the GSHS report 2017 as food from a fast food restaurant, such as BBQ takeaway, Hot Curry takeaway, Country Fried Chicken takeaway and Fish & Chips takeaway on three or more days during the past 7 days (WHO et al. 2017; WHO 2020b)

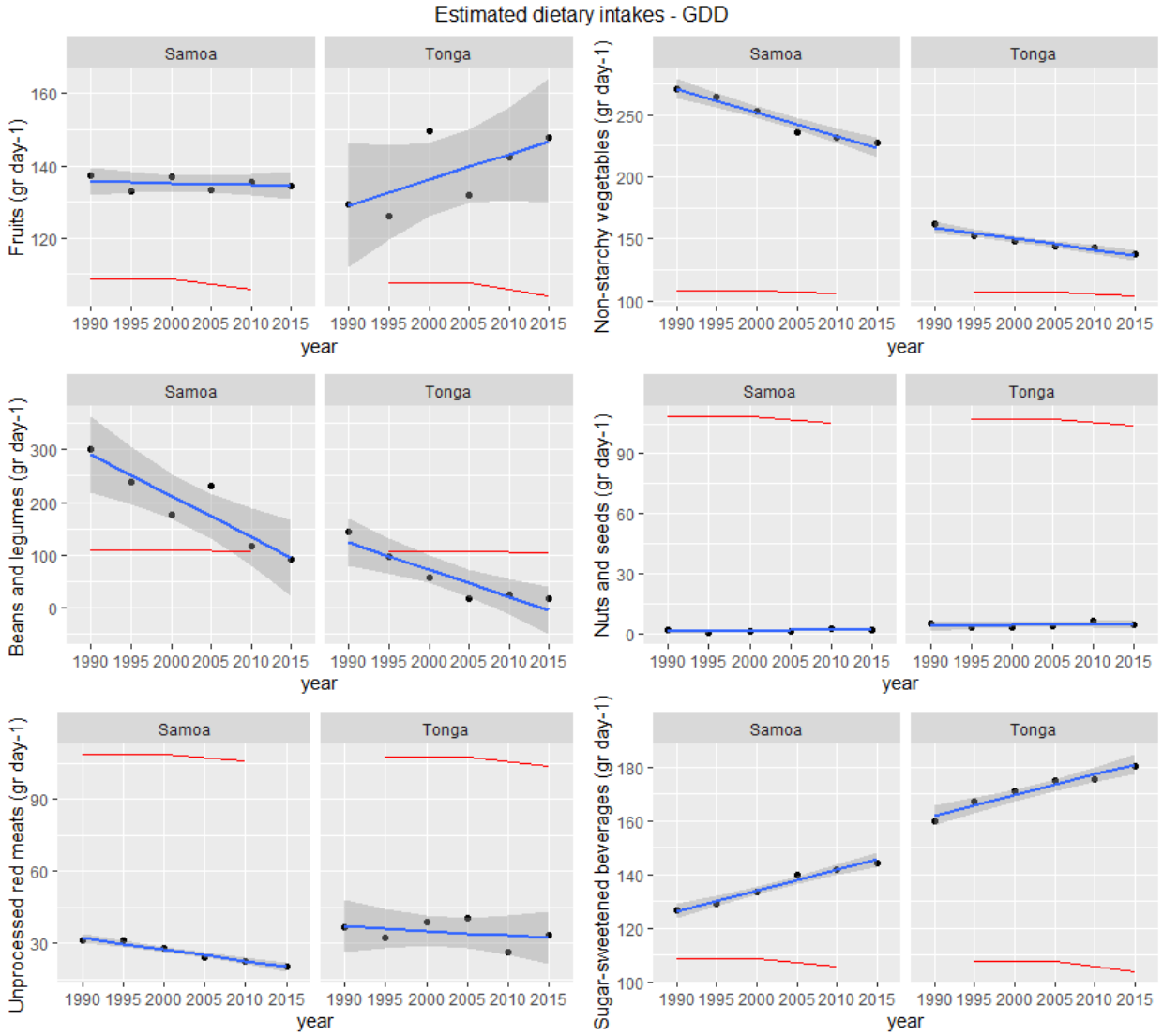


Figure 1 *Estimated dietary intakes in each country. Redline = global average (Global Dietary Database 2020).*

b. Food sources

In Samoa, over 60% of the approximately 2,800 consumed energy (kcal/capita/day) originates from purchased food items, compared to 31% from own production, which exemplifies the nutrition transition in the country (Choy et al. 2017; FAO et al. 2020; Troubat et al. 2020). The concept of **nutrition transition** captures the shift from traditional diets and movements towards physical inactivity and increased consumption of less healthy and highly processed foods (Popkin et al. 2020).

In 2015, the main cultivated crops included coconut, taro, banana, breadfruit, cocoa, giant taro (Ta'amu) and Taro palagi (Morrell 2010; Francis and Dietershagen 2017; SPC 2020). Although, Samoa's export market is dominated by frozen fish, which was around 24% of the total export value in 2018 (FAO 2019; Troubat et al. 2020). Likewise in Tonga agriculture accounts for a major source of livelihood and economic activity (19% GDP) (Ma'asi and Francis 2020). Eighty-five per cent of households rely on subsistence agriculture, while only 5% farm commercially. The commercial farm sector declined significantly over the years from 24% in 2001 to 5% in 2015 (Woodfine 2019). The import of beef has tripled from 2008 to 2014 from 250–805t, and the volume and value of cereals have increased (Tonga Statistics Department and Secretariat of the Pacific Community 2017; Ma'asi and Francis 2020). The majority of cash-based items are

chicken, bread, biscuits and crackers, butter and preserved meat, while around 50% of fruit and vegetable expenditure comes from subsistence, as do most of the consumed root crops (Ma'asi and Francis 2020).

Historically, communities and the population depended on the trade of agricultural and fishing products among one another. Over time the food trade flows shifted, and the region is more dependent on food imports from the global market, displaying a negative food trade balance. Lameko (2020) describes how the traditional meals *meaai aano*, consisting of taro, yam, and breadfruit and *meaai lelei* (taro leaves (palusami), chicken and other birds, fish and other seafood, and pork), are almost completely replaced by more processed and imported foods. These include bread, rice, and imported meats such as mutton flaps, turkey tails, fresh, salted and canned beef, and factory-farmed chicken. The traditional drinking coconut has been replaced with sugar-laden beverages (FAO and SPC 2019; Lameko 2020). This is in line with findings from a qualitative survey by FAO and SPC in 2019 in Samoa, while previously most food items were locally produced, higher consumption of purchased and imported foods is visible at all mealtimes. The communities reported a preference for local food items. However, it is more convenient to buy from the stores and supermarkets, which further shows the high reliance on imported food items. Linked to those dietary changes, the increased consumption of processed, high calorie and sodium, and low nutrient content food, is the large increase (60%) from 2005 to 2014 of food imports (FAO and SPC 2019).

Thus, the main imported products are processed foods, such as spam, canned meat, and baked goods. As intra-regional trade is limited, the key food products are imported from China, Japan, Thailand and Vietnam, and on a smaller scale from the Republic of Korea, France, the United States, Australia and New Zealand (WFP and SPC 2018). Altogether, the imports of edible food with nutritional value in Tonga and Samoa have almost tripled and quintupled during the last 30 years, contributing to over half of the consumed food, whereas exports remained relatively the same (FAO et al. 2017; FAOSTAT 2020) (**Figure 2**). (FAO et al. 2017).

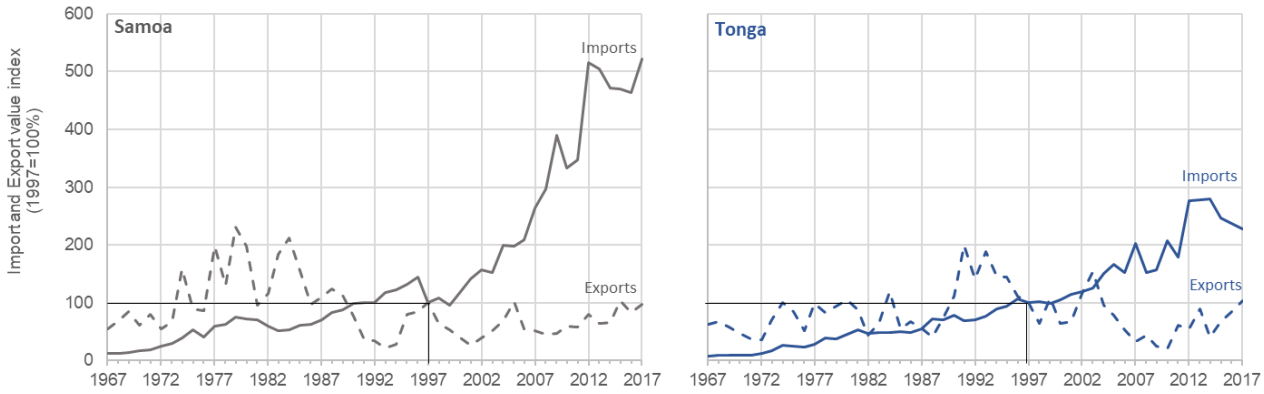


Figure 2 *Import value index for all edible foods with nutritional content excluding fish relative to 1997 (FAOSTAT 2020). Black line= reference year.*

The over-dependency on imports led to a reduction in the quality of the diet in both countries. The high levels of food imports are linked to high levels of remittances, making food security in both countries extremely fragile (McGregor et al. 2016).

In Tonga, agriculture exports are dominated by root crops, squash, coconut, melon, vanilla, and frozen and processed fish, as well as high-quality fish fillets (WFP and SPC 2018; Woodfine 2019; Ma'asi and Francis 2020). However, the main challenge is the ability to compete within the market systems, as most producers lack the financial means to buy agricultural inputs to transition into commercial production. Additionally, frequent natural disasters have a negative effect on the export and import of Tongan commodities, thus

securing the self-sufficiency of staple crops must be a top priority (Woodfine 2019; Ma'asi and Francis 2020). This holds for both countries, which display a negative trade balance.

c. Food security level

Historically, due to the different ways and varieties to access food, such as subsistence farming, training and selling products, fishing and hunting, food security was traditionally strong within the region. However, through rapid urbanization and growing reliance on cheap and unhealthy food imports, food-insecurity has increased.

According to the **food insecurity experience scale** (FIES), one of the SGD indicators, 26.8% of the households in Samoa are moderately food insecure, with large regional disparities, which can be classified into two areas Apia and North West Upolu and the rest of Upolu and Savai'i (Troubat et al. 2020). The latter displays severe FIES prevalence and less diversity in food supplies with on average ten different food items, while the other area displays the lowest prevalence and the broadest diversity, with an average of 20 different food items (FAO et al. 2020; Troubat et al. 2020). Highlighting, that food security and diversity is different across the regions/islands within both countries.

Another SDG2 indicator (also an additional indicator to display food security) is the **prevalence of undernourishment** in a country. From 2013 to 2017, the prevalence of undernourishment decreased in Samoa from 2.9% to 2.7%, while in 2019 the prevalence decreased below 2.5% (FAO et al. 2020; Johns Hopkins University 2020; Troubat et al. 2020). Data for Tonga are not available for this indicator.

d. The triple burden of malnutrition

Chronic malnutrition rates of Samoa and Tonga are below the world prevalence rates; however, they are in line with the prevalence of overnutrition. Prevalence of **moderate and severe stunting and wasting** for children below the age of 5 years are at 7.3% and 3.1% (2019/20) in Samoa, and lower in Tonga at 2.2% and 1.1% (2019) (TSD et al. 2019; Global Nutrition Report 2020a; SBS et al. 2020). Likewise, the prevalence of moderate and severe **underweight is** lower in Tonga (0.8%) than in Samoa (3.4%) (TSD et al. 2019; SBS et al. 2020).

Hardly any current data can be found on the national prevalence of **micronutrient deficiencies** for both countries. Though the newest multiple indicator cluster surveys (MICS) by UNICEF and partners in 2019 reveals that over half of the households in Tonga consume iodized salt (52.9%) (TSD et al. 2019; UNICEF 2019), whereas 95.9% of the households indicate the use of iodized salt in Samoa (SBS et al. 2020). Cross-sectional data from Samoa collected in 2015 by Choy et al. (2018) indicates that **59%** of children 24 to 59 months of age are not meeting their recommended dietary allowance **(RDA)** for **calcium** and **26%** display **inadequate intakes of vitamin A and E** (Choy et al. 2018).

As mentioned, the region and thus both countries have some of the '*fastest growing rates of overweight and obesity* in the world', entering now an alarming level (Blankenship et al. 2020, p. 1), and has been called the NCD capital of the world (Win Tin et al. 2020). One in 18 children in Samoa (8.7%) is **overweight** (SBS et al. 2020), and 11% of the children in Tonga (TSD et al. 2019). In 2016, in Samoa, 47.3% of adults were **obese**, while in 2013, 89% of the population were **overweight or obese** (SBS et al. 2020; FAO and SBS). Similar numbers are observed in Tonga. In 2017, 87% of the population above 15 years were reported to be **overweight or obese** (Tekiteki et al. 2014; Tonga Statistics Department and Secretariat of the Pacific Community 2017), of which 48.2% were **obese** (FAO et al. 2020; Global Nutrition Report 2020a). Slightly more women are overweight/obese (93.4%) compared to men (86.5%) (Tekiteki et al. 2014; Tonga Statistics Department and Secretariat of the Pacific Community 2017), which holds within the

categorization of obesity. In Samoa and Tonga, around 55% and 54% of women are obese, compared to 39% and 41% of men (WFP and SPC 2018).

Adding to the burden is the increase in the prevalence of **adult diabetes**. In 2014, in Samoa, 23% and 27% and Tonga 22% and 26% of male and female adults were classified with type II diabetes, compared to the world average of 8% and 24% in Polynesia (Johns Hopkins University 2020). Additionally, in 2015 over 20% of the adults in both countries had raised blood pressure (≥ 140/90 mmHg) (Johns Hopkins University 2020; FAO and SBS). Over 80% of deaths are due to NCD in Samoa and Tonga, including cardiovascular diseases and diabetes (Santos et al. 2019; WHO 2020c). In Tonga, the country recognised rising levels of morbidity and lower life expectancy linked to cardiovascular diseases, diabetes and hypertension and obesity (Veatupu et al. 2019; Ma'asi and Francis 2020).

In both countries, unhealthy and poor diets are identified as the main drivers of increased risk of developing cardiovascular diseases, cancer and chronic respiratory disease. Additionally, poor diets are linked with the rise of disabilities and early death caused by **NCDs** (75-80% in Samoa) (Troubat et al. 2020; FAO and SBS). Other determinants related to the high and increasing prevalence of NCDs are the lack of physical activities, tobacco, harmful use of alcohol, the colonial influence, modernization, globalization and the rapid urbanization and international migration, as well as influence of social norms, food aid, increase intake of imported foods, and changes within the diet (World Health Organization 2018; FAO and SPC 2019; Lameko 2020).

Table 1 *Summary of food and nutrition security indicators of Samoa and Tonga*

Food and Nutrition Security Indicators	Samoa	Tonga	World average	Polynesia	References
FIES	26.8% moderate food insecure	no data	25.9% Moderate or severe food insecurity	n.a.	(FAO et al. 2020; Troubat et al. 2020)
Malnutrition rates					
Moderate and severe stunting (height-for-age)*	7.3% (2019/20)	2.2% (2019)	21.3% (2019)	n.a.	(TSD et al. 2019; FAO et al. 2020; Global Nutrition Report 2020b, a; SBS et al. 2020)
Moderate and severe wasting (weight-for-height)*	3.1% (2019/20)	1.1% (2019)	6.9% (2019)	n.a.	
Overweight* (weight-for-height	8.7% (2020)	11% (2019)	5.6% (2019)	5,3% (2014)	(TSD et al. 2019; FAO et al. 2020; Johns Hopkins University 2020; SBS et al. 2020)
Adult obesity (BMI >=30))	49% (2016)	49% (2016)	13% (2016)	52% (2016)	(Johns Hopkins University 2020)
Non-communicable diseases					
Adult diabetes	Female 27% Male 23%	Female 22% Male 26%	Female 8.2% Male 9.0%	Female 24% Male 23%	(Johns Hopkins University 2020)

*children <5years of age
n.a. data not available

e. Food and nutrition security challenges

As described above, fish is an important source of protein and income within the Pacific region, with the majority originating from coastal fishing. The changing climate has a negative effect on coral health and marine-ecosystem stability, as well as the higher cyclone risk and frequency of tropical storms, and can destroy the fishing infrastructure and marine ecosystems (WFP and SPC 2018). While natural hazards and disasters have an immediate effect on agricultural production, simultaneously they also affect the import of food products, increasing prices and food scarcity as food is less available in the markets (Troubat et al.

2020). As mentioned above, households in both countries are highly dependent on food imports for their daily dietary intake.

f. Existing research and development interventions promoting the use and consumption of biodiversity for food and agriculture

Increasing national production and consumption of nutritious, unprocessed and fresh foods will significantly contribute to decreasing unhealthy diets and imports/remittance dependence and increasing healthier diets and self-reliance (FAO et al. 2017; Win Tin et al. 2020). In general, recommendations and suggestions include interventions that are linked to increased consumption of a range of food items, like pumpkin, papaya, fish and seafood, and the support of increased consumption of dark green leafy vegetables, vitamin A-rich fruits and vegetables (Troubat et al. 2020; FAO and SBS).

Other suggestions and recommendations by FAO and the Samoa Bureau of Statistics to positively influence healthy consumption includes three areas. The first targets trade and market-related measures, such as reducing the price of local fruit, vegetables and animal products by investing in the improvement of efficiency of the local food production and distribution systems. It also supports incentives to reduce the consumption of foods and beverages with high sodium, sugar or fat content (FAO and SBS). The second area includes measures to increase access to affordable and nutritious foods by the households. This involves food voucher schemes, nutritious school-feeding programs, and working with manufacturers to reduce sodium content in food products. This latter includes initiatives that encourage households to reduce the addition of table salt and sugars to meals and to use fortified flour, rice and milk products with micronutrients such as vitamin A. The third area targets the production side with investments in improving the efficiencies of production of local foods, and food production and distribution systems (FAO and SBS). Overall, these targets address the need for a sustainable food system.

Local and traditional species and varieties can play a central role, particularly after dismantling perceptions that associate them with poverty or low status (Englberger 2011; FAO et al. 2017). Local varieties are generally nutrient-rich (Englberger 2011), and interventions such as backyard gardens in urban and rural settings can contribute a significant amount of vegetables. For example, in two years, a backyard garden program in Antigua and Bermuda produced 280 tonnes yr^{-1} of vegetables, and the overall goal is to produce 1,800 tonnes yr^{-1} (WHO 2020). This amount is quite significant considering Samoa imported 3,000 tonnes of vegetables and 2,000 tonnes of fruits in 2017 (FAOSTAT 2020).

In Tonga, the Ministry of Health (MoH) and Ministry of Commerce, Trade and Industries (MCTI) played an active role in the development of Tonga's 2014 Food Act, however, the responsibility for adequate provision of food is vested in the Ministry of Agriculture, Food, Forests and Fisheries (MAFFF). In 2007, the MoH established TongaHealth an independent body under the health promotion foundation act, in partnership with other government ministries and civil society. The initiative implemented policies within the 2015 to 2020 national strategy for prevention and control of NCDs (Ma'asi and Francis 2020). The TongaHealth programme includes a home garden component, which provides resources to increase the consumption of eight local fruits and vegetables (FAO and Commission on Genetic Resources for Food and Agriculture 2019). Additionally, a number of initiatives to increase fish, fruit, vegetables and livestock production and promote healthy eating and diversification of diets have been going on since 2004. These include school, community and home gardening; nutrition and healthy cooking education programmes targeting women and schoolchildren; and providing seedlings to schools and women's groups in cooperation with community-based training sessions on agriculture, health and nutrition. Some success was demonstrated in vegetable consumption, which increased from 2004 from 8 to 37%. A different

initiative to promote school gardens, good nutrition and healthy eating since 2012 was called *Mai e Nima* (give me five) (Ma'asi and Francis 2020).

Table 2 *Summary table of food and nutrition security projects within the Pacific region*

Country	Project	Achievements	Contribution to biodiversity for food and agriculture	Reference
Pacific Region	Promoting nutritious food systems in the Pacific (PNFSP)	2016-2020 6 countries; budget of US$2million		(El-Zabri 2019)
Samoa	Samoan Agriculture and Fisheries productivity and marketing project (SAFPROM)	Pipeline project by IFAD	• Facilitates establishment of a conducive policy • Regulatory environment for local crops and fisheries • Promotes private sector investments in sustainable and nutrition smart value chains	(El-Zabri 2019)
Tonga	TongaHealth	2015-2020	• Home garden component, provision of resources to increase consumption of eight local fruits and vegetables	(FAO and Commission on Genetic Resources for Food and Agriculture 2019; Ma'asi and Francis 2020)
Pacific region	INNOV4AGPACIFIC	Ongoing Action plan for 4 priority areas: nutrition and income, finance, ICTs and weather risk insurance, by learning from good practices, innovations and critical success factors that were determined to be of high relevance for enhanced performance	• Garden to fork strategy • Fostered shared understanding of constraints and opportunities of local food crops and fishery value chains	(FRIEND 2020; Iese et al. 2020)

3. *Agricultural systems and biodiversity for food and agriculture*

This section explores the sufficiency of the current diversity within the agricultural production system, its characteristics, and the prospect of new production systems that contribute to diversity, climate change resilience and livelihoods.

a. National agriculture production patterns

Various reports stress the urgency for designing production systems adapted to the current global and climate-related challenges faced by the Pacific Island states (FAO et al. 2009; Taylor et al. 2015; McGregor et al. 2016; Win Tin et al. 2020). In the Pacific region, production systems are in general following a conventional path of external input dependency, maximisation of yields and oversimplification with rapid erosion of traditional farming practices, local diversity (at the species and variety level) and soils (McGregor et al. 2009, 2016; Jaenicke and Secretariat of the Pacific Community 2011; Wairiu 2017). Some regions have already experienced the large negative effect of oversimplification (i.e. 1990 taro's crash due to leaf blight in Samoa), yet the role of diversity as insurance against pests and diseases, extreme weather events and food insecurity remains overlooked or unvalued (Kambuou et al. 2007; McGregor et al. 2009; Taylor et al. 2015).

Agriculture contributed to the national GDP of 9.8% in 2019 in Samoa and 17.2% in 2016 in Tonga (latest reported year) and employment 30.4% in Samoa and 24.2% in Tonga of the total employment in 2019 (FAOSTAT 2020). Both Samoa and Tonga report producing at least 20 crop groups covering 31 crops of which 20 are unique to one of the countries (**Figure 3**). Despite the relatively high crop production diversity, coconut production represents 70% of the overall production and occupies 58% and 30% of the cultivated area in Samoa and Tonga respectively (FAOSTAT 2020). The coconut area increased by approximately 203 and 84 ha per year in Samoa and Tonga since 1995 (FAOSTAT 2020). Taro, yams, and bananas crop areas also increased in Samoa but to a lesser extent (89, 78, 59 ha per year, respectively). Whereas in Tonga fruits, groundnuts, and pumpkins expanded the crop area by 83, 47, 44 ha per year respectively. Tonga reports crop area reductions mainly for Taro and Cassava with 14 and 69 ha per year, whereas crop areas for other crops in Samoa remained relatively stable (area expansion <20ha per year).

Overall, the harvested agricultural area increased in both countries by around 506 and 228 ha per year since 1995 (FAOSTAT). Likewise, imports of external inputs are increasing. Samoa imported 103 tonnes of pesticide in 2017 and 68 tonnes of fertilizers in 2018, imports had increased by 2.4 and 0.2 tonnes per year since 2002 respectively (FAOSTAT). In Tonga, fertilizer imports drastically increased during the last nine years (19 tonnes per year, 260 tonnes in 2018) whereas pesticides remained almost constant (0.1 tonnes per year, 23 tonnes in 2018) (FAOSTAT). Fertilizer import cost is 1.2 times higher in Samoa than in Tonga (Samoa US$ 633 per ton, Tonga US$520 per ton) (FAOSTAT).

Despite the increments in fertilizers and pesticides, yields for nine out of 21 crops in Samoa and 14 out of 20 crops in Tonga have decreased since 1995 (FAOSTAT). Although avocado, taro and tobacco increased annual yields by over 0.079 t/ha/year whereas tomatoes, coconuts and cassava increased to over 0.16t/ha/year in Samoa and Tonga, respectively. Crops with yields 1.5 times larger than global averages include tobacco, mangoes, avocadoes in Samoa; and cassava, coffee, yams, coconuts and vanilla in Tonga. On the other hand, fruits, bananas and vegetables all reported 0.5 times smaller yields than global averages in both countries (FAOSTAT 2020).

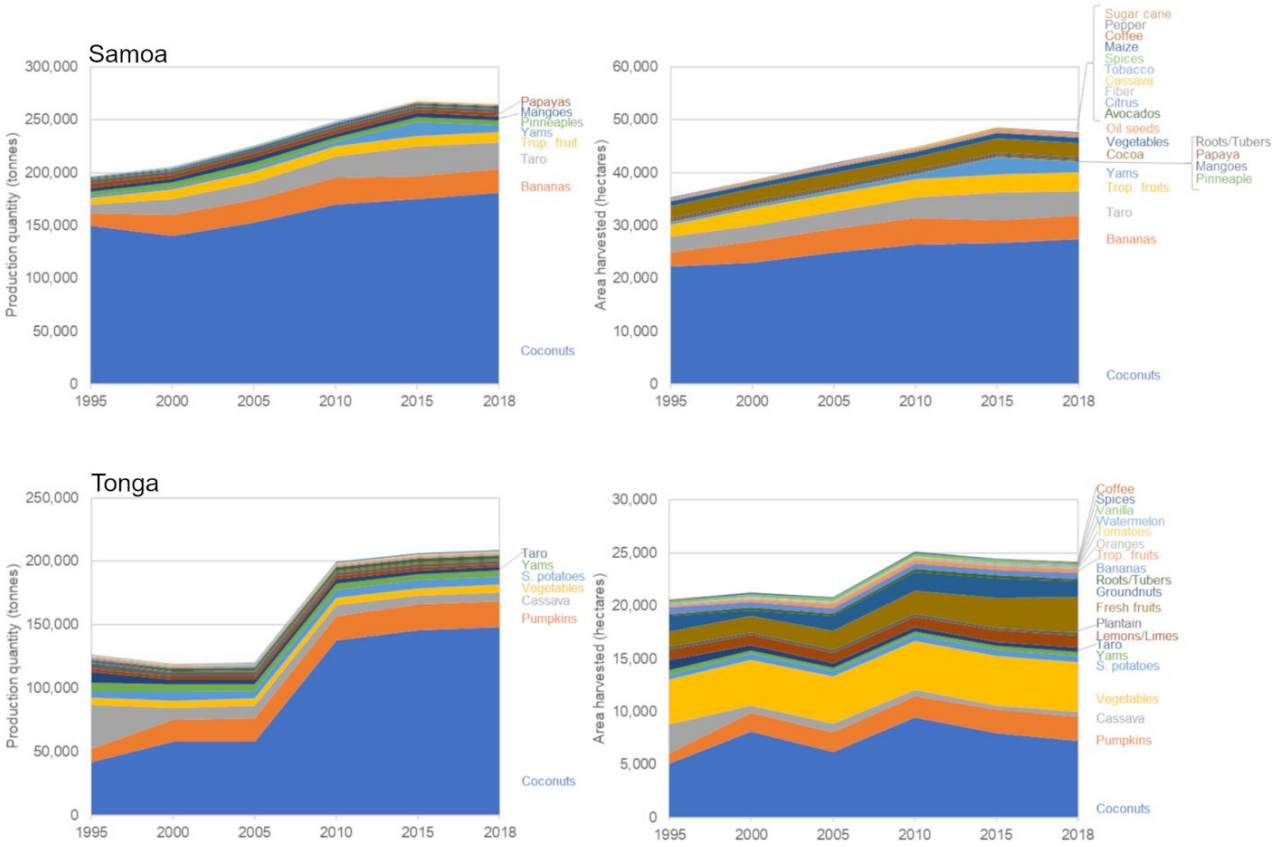


Figure 3 Production quantity (on the left) and area harvested (on the right) for all the crops reported by Samoa and Tonga from 1995 until 2018 (FAOSTAT).

b. Crop-based production systems characteristics in the two countries

Pacific Islanders depend on crop production and fishing for their livelihoods (Singh 2019). Samoans and Tongans, mainly cultivate traditional farming systems that are based on subsistence, shifting cultivation, fallow and intercropping. Traditional farming systems are resilient and host high crop species and cultivar diversity including mixtures of cash crops, food crops and more importantly fruits, nuts and vegetables year-round, as well as diversification with agriculture, livestock and fishing (McGregor et al. 2009; Taylor et al. 2015). Over the years, the systems have evolved into semi-subsistence whereby the surplus from the household is sold in the market (ICHCAP 2014; McGregor et al. 2016). Other systems are cash-crop driven, where species such as eggplant, kava, papaya, pumpkin, squash, vanilla and watermelon contribute to the national economy (Halavatau and Halavatau 2001; McGregor et al. 2016).

In Samoa, shifting cultivation is traditionally executed through the multi-storeyed fallow system (See **Table 3**). For example, root crops are intercropped with coconut and other trees thereby diversifying farmers' livelihoods (Tikai and Kama 2010). Another common traditional agricultural practice is taro terracing with stones and flood irrigation (FAO et al. 2016).

Samoa's upland habitats are largely intact with a high forest cover undisturbed by human activities, while the lowland habitats consist of cultivated areas and lowland forests. The island Savaii is still dominated by native species, while Upolu's are 99% non-native. Several different farming systems are used, such as livestock grassland-based and landless systems; naturally regenerated forests; planted forests; self-recruiting capture and culture-based fisheries; irrigated crops and rainfed crops, and mixed systems (agropastoralism - cattle under coconuts/cocoa) and agro-forestry (FAO 2019).

In Tonga, farming systems are fundamentally based on non-permanent agroforestry with periods of fallow and a series of intercropping. Nearly two-thirds of the agricultural land has been utilised for root crops cultivation (Halavatau and Halavatau 2001). The production system includes livestock grassland-based and landless systems; naturally regenerated forest; planted forests; self-recruiting capture fisheries; irrigated crops; rainfed crops, and mixed production systems. Traditionally, farmers cultivate the land for about three years before the land lies fallow for a longer period. Additionally, multi-crop garden systems, protected by trees either within the garden system or by including the forest reduce extreme events-related risks for crops. In total, four different agroforestry systems were identified by Makino in 1993, traditional agroforestry systems – home garden style; traditional agroforestry system – slash and burn, commercial agroforestry – a combination of traditional and modern systems, and urban agroforestry – home garden style. Around 42% of the arable land is farmed, based on smallholdings averaging 3.3ha. Root crops (yam, taro varieties, sweet potato and cassava) dominate the rain-fed cropping system, common fruit trees include avocado; banana/plantain; breadfruit; canarium nuts; citrus coconuts; mango; Pacific lychee papaya; pineapples; plum, and watermelons. Tonga currently has no commercial fruit orchards and domestic production in place (Vainikolo 2019; Woodfine 2019).

Table 3 *Different traditional practices that facilitate spatial and temporal integration of plants and animals in Tonga and Samoa*

Name of the practice/strategy	Practices with	Benefits	Limitations	References
Local Indigenous Crops/varieties	Apple, arrowroot, breadfruit, banana, coconut, kava, mountain, pandanus, potato, sago, taro varieties and yam Sweet	• High in nutritional value providing macro and micronutrients. • Root crops (cassava, cocoyam, sweet potato, taro) require low nitrogen. •	Susceptible to climate change hazards such as cyclones or drought.	(McGregor et al. 2016; Singh 2019)
Agroforestry	Root crops (ginger, taro, yam), multifunctional trees (fruits, nuts, medicinal, cultural value, wood source, timber), vetiver grass (as edge crop)	• Provides resilience against natural disasters. • Increases food security. • Minimises erosion and land degradation. • Provides coastal protection. • Protects ground crops from vulnerability towards extreme weather such as strong wind. • Provides a natural habitat for animals. • Increases above- and belowground carbon stock.	Simplified (e.g. low plant diversity) systems are vulnerable to climate change.	(FAO 2010; Tikai and Kama 2010; FAO et al. 2016; McGregor et al. 2016; Wairiu 2017)
Alley cropping	Grass strips, live hedgerows and taro and Leguminosae trees	• Reduces deforestation. • Controls soil erosion. • Maintains soil fertility.		(FAO 2010)
Fallow Period		• Recycles organic matter such as weeds and crop residues. • Allows nutrients regeneration before the land is used for replantation.	Shorter fallow period limits the chance for the forest to regrow.	(Tikai and Kama 2010; ICHCAP 2014; FAO et al. 2016; McGregor et al. 2016)
Intercropping	Banana with coffee; Coffee, cocoa, coconuts, bananas, kava with timber; Kava with taro; Coconut with cocoa; Plantain, taro with yam.	• Provides resilience against natural disasters. • Creates favourable conditions for the soil, water and nutrients. • Compatible mixtures can improve yield. • Controls weed infestation. • Contributes to farmers' income.		(Tikai and Kama 2010; FAO et al. 2016; McGregor et al. 2016)
Mixed cropping	Various crops planted together simultaneously without a distinct area.	• Maintains soil fertility. • Creates favourable conditions for the soil, water and nutrient cycling.		(Tikai and Kama 2010)
Multi-storeyed	Casuarina and coffee	• Provides resilience against natural disasters. • Protection of understorey crops from excessive water, heat, and drying winds.	Combinations of multi-level crops may be hard to manage without a systematic approach.	(Tikai and Kama 2010; FAO et al. 2016; McGregor et al. 2016)
Non-tillage	Taro	• Maintains soil fertility. • Minimises weed control. • Requires lower labour inputs.	No significant differences in yield between tillage and non-tillage cultivation.	(Tikai and Kama 2010)

Name of the practice/strategy	Practices with	Benefits	Limitations	References
Pond-field	Taro varieties	• Highly tolerable towards saturated soil conditions.		(FAO 2010)
Raised-Bed	Root crops such as sweet potato	• Improves productivity. • The system typically comprises the formation of raised beds of soil or decaying plant materials. Soil material is often sourced from surrounding ditches which in turn encourages drainage in swampy or low-lying areas.		(FAO 2010)
Shifting cultivation/Slash and burn	Banana/plantain, giant taro, kava plantain and cassava, paper mulberry, sweet potato, taro, yam	• Increases or maintains soil fertility. • Allows nutrients regeneration before the land is used for replantation. • Allows sunlight to penetrate the ground forest area.	Involves burning. Requires long fallow periods to recover (>8years).	(Gillett 2011; ICHCAP 2014; FAO et al. 2016; McGregor et al. 2016)
Terrace Garden	Taro varieties	• Terracing improves soil condition by trapping silt and debris. • Minimises coral reef siltation. • Implemented along with irrigation systems protects crops such as taro from beetle attack.	Labour intensive.	(FAO et al. 2016)

c. Fish-based production systems characteristics in the two countries

Coastal and subsistence fishing remains the most common fishing practice and the main source of protein in both countries (Gillett 2011). Subsistence fishing is essential for food security especially in rural areas by providing diverse seafood (i.e. finfish, octopus, giant clams, turbo, cab, seaweed, anadara (clam). Nonetheless, the reduction in marine resources due to coral degradation combined with overfishing and the labour intensiveness of subsistence fishing is resulting in fish consumption below recommended levels (Gillett 2011; Francis and Dietershagen 2017; FAO 2020a). Yet, in Samoa and Tonga, fish apparent consumption per capita was above the global average (~48.5 and 23.3 kg per capita respectively[3]) in 2013 compared to 20.5 kg globally in 2018 (FAO 2020a).

Aquaculture is progressing slowly with a foreseeable future commercial prospect (Adams et al. 2001). In Samoa, previous attempts to cultivate tilapia in 1954 followed by seaweed, giant clam, green mussel and red claw crayfish were unsuccessful. Even so, a new national economic strategy through AusAID, the village fisheries extension project, was established to actively promote aquaculture focusing on tilapia, mullet and giant clam (Adams et al. 2001). Aquaculture in Tonga was initially tried in 1968 with tilapia and milkfish and during the 1970s, various attempts to cultivate a variety of shellfish namely oyster, mussel and pearl oyster were also made. The government has now established a hatchery for giant clam, green snail and trochus and Cladosiphon and black lip pearl oyster (Adams et al. 2001). Despite these efforts, aquaculture production is comparable with freshwater fish production (0.3 tonnes Aquaculture vs 1 tonne Freshwater

[3] http://www.fao.org/state-of-fisheries-aquaculture

in Tonga and, 12 tonnes Aquaculture vs 12 tonnes Freshwater in Samoa per year) but extremely low compared to coastal subsistence fisheries (3,000 and 5,000 tonnes in Tonga and Samoa respectively per year) (FAO 2020b, c).

d. Livestock-based production systems characteristics in the two countries

Agricultural systems can also be integrated with livestock. Land feedstock that is combined with the agroforestry system is known as agro-silvopastoral. Similarly, aquaculture can be integrated as an aquaculture-crop-livestock system. This method creates a sustainable and resilient system emulating the interdependency between the ecosystem itself, for instance, free-range livestock would benefit the crops through weed control and organic fertilization from the manure (FAO, 2016). Livestock husbandry is common in many households and serves as an indication of the society's wealth and social status, cultural and religious purposes, and source of protein as well as income. Common livestock production systems include a) traditional subsistence b) smallholder and c) commercial. Livestock in both islands is dominated by cattle and pigs, although other species are also present, goats, sheep, buffalo, horses, donkeys, rabbits, poultry and honeybees (**Figure 4**; FAO, 2016, McGregor and Dawson, 2016, FAO).

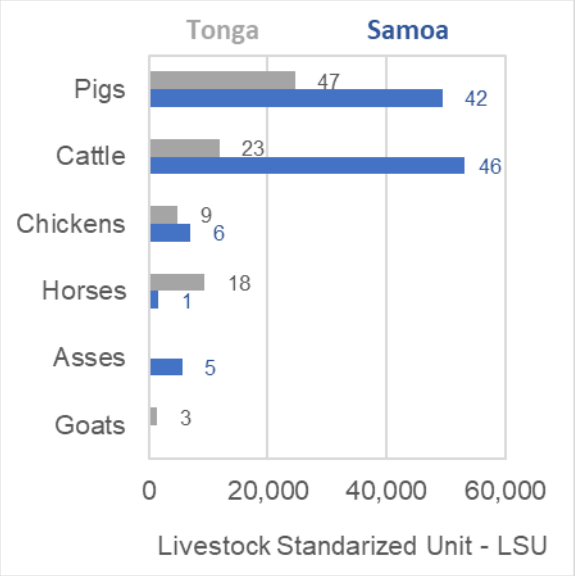


Figure 4 *Livestock reported in 2018 converted to livestock standardized units and as percentage numbers (next to bars).* *LSU (Livestock Standard Unit) conversion units includes pigs=0.3; cattle=1, chickens=0.014, horses=0.8, asses=0.8 and goats=0.1 (FAOSTAT).*

The most common livestock produced in Samoa and Tonga are chickens and pigs. Chickens were introduced in the Pacific Islands years ago and two main genetic lineages are identified a) clustered in Fiji, Samoa and Tonga and b) centred in Niue, Solomon Islands and Vanuatu. The traditional method of subsistence breeding through the free-range system has proven to be resilient towards climate change. For commercial purpose, poultry is sourced mainly from Australia and New Zealand and common breeds include Leghorns, Rhode Island Reds, Black Australorps, Brown Shaver, White Shaver and Cobb (McGregor and Dawson, 2016). Pigs carry significant traditional and cultural values (e.g. recreational small-scale hunting, social obligations - gifts (Ministry of Natural Resources and Environment (MNRE) 2016; Ministry of Agriculture and Food, Forestry and Fisheries). Three types of pig known within the region are local, a crossbreed between local and exotic breed and the exotic breeds such as Large White, Land Race, Duroc, Hampshire, Saddleback, Tamworth and Berkshire. Pigs are normally raised in communal pigpens or free-range, although those sometimes wander around destroying the cultivated area (McGregor and Dawson, 2016, FAO).

The Pacific Community (SPC) highlighted several constraints with livestock production including lack of priority on the legislation involving livestock, the capacity of infrastructure and inadequate resources (e.g. veterinarians, good quality local feed, genetic resources, farm breeder's finance and technology) (FAO, 2016). Some efforts are ongoing for instance in Tonga, a GEF-funded Integrated Land and Agro-Ecosystem Management Systems project seeks to maintain the balance of agriculture production with forest ecosystem services for the ecosystem balance. Amongst the activities is the provision of organic fertiliser from pig manure (FAO, 2016).

e. New production systems that contribute to diversity, resilience and livelihoods

The natural ecosystem can benefit from organic farming practices as it enhances the ecological processes and biodiversity whilst adapting to the local conditions. Land that is managed sustainably can host more species and provide semi-natural habitats for the ecosystem (FAO et al. 2016). Mixing farming systems with organic farming has high potential and can play a dominant role in addressing the food system issues in the Pacific Islands. The SPC organised development and implementation of the Pacific Organic Regional Development Strategy, which envisions organic farming initiatives covering: a) proper ecosystem management that protects and enhances biodiversity and the primary ecosystem b) proper soil and water conservation through sustainable traditional farming methods and recycling of rainwater for irrigation, and c) proper management of wild harvests. These objectives can be achieved with lower fossil fuel use for energy and synthetic fertilisers as well as an emphasis on internal farm inputs such as composting and other activities for recycling organic waste (SPC 2008).

In Samoa, Women in Business Development Incorporated (WIBDI), established in 1991, has been advocating organic farming support to over 200 rural villages across the country. WIBDI's main project was the Virgin Coconut Oil Project that involves organically certified farmers exporting virgin coconut oil for the cosmetics company, The Body Shop, 2007 (Bell 2009). In Tonga, Tonga National Youth Congress plays a vital role in promoting organic agriculture. An educational programme called "Walk the Organic Talk: Organic Farm Visits" was organised focusing on groups such as tourists from agri-tourism activities, local farmers, teachers and particularly youth as well as school students. Collaboration between countries was also evident, as WIBDI from Samoa had assisted with the mapping of the vanilla farms in Tonga in preparation for organic certification (Bell 2009). Organic farming can be further expanded and promoted as the Pacific Island nations are the perfect platform with their common agricultural practices still dominated by traditional practices (Bell 2009).

The growing population and urbanisation may require modification of the traditional backyard garden as practised previously. A continuing focus on low energy and low input crop production has been encouraged in Samoa and is feasible using recycled buckets or bamboo as a container with a simple hose for irrigation of the crops. This simple model can perfectly accommodate the household with a small yard, as it does not require a lot of space. This method has also been introduced in other Pacific Island countries of Kiribati and Tuvalu (SPC 2015).

A focus on marine harvests can be further explored through diversified and sustainable aquaculture. The development of aquaculture in the Pacific Islands has been slow despite its benefits, except in French Polynesia and New Caledonia. Pearl farming in French Polynesia and shrimp farming in New Caledonia generated USD173 million and USD29 million respectively in 2007 (Bell et al. 2011). The Pacific Islands have great potential to further develop the aquaculture industry considering a) viable species that can be cultivated through aquaculture are in high demand in Asia such as groupers, sea cucumbers, spiny lobsters, giant clams and green snail; b) the geographical location and coral reef lagoons with suitable conditions and proximity to the Asian market, and c) understanding of the marine resources in that the coastal communities are already familiar with many of the marine species (Adams et al. 2001). Slow development of aquaculture in the Pacific Islands is largely due to lack of policy and legislation frameworks. Nonetheless, efforts in planning to overcome technical, logistical and socio-economic constraints are in place to promote the activity (Bell et al. 2011).

4. Climate-change mitigation strategies in Samoa and Tonga

In this section, climate-change mitigation strategies and the use of biodiversity for food and agriculture are investigated. Current and projected events are identified as well as current strategies in production systems and management options, including findings of existing research and development interventions.

a. Current and projected extreme events

As two of the SIDS in Polynesia, the climate in both Samoa and Tonga is categorised as tropical, with maritime mild to warm temperatures and high humidity, with little seasonal variation. The rainy season in Samoa is from November to April, with an average of 2900mm annual rainfall, which is highly dependent on the location and latitude (Centre for Australian Weather and Climate Research and Commonwealth Scientific and Industrial Research Organization 2011; FAO 2019; CIA 2020). In Tonga, the recorded annual rainfall is 1,728mm to 2,280mm depending on the island and the warm-season is from December to May (Tonga Statistics Department and Secretariat of the Pacific Community 2017; Woodfine 2019).

Both islands are prone to natural disasters, such as cyclones, flash floods, and earthquakes (FAO 2019; FAO and Commission on Genetic Resources for Food and Agriculture 2019). Tonga is ranked the second most at-risk country in the world to natural hazards. For example, the cyclone *Ian* in January 2014 destroyed 90% of the telecommunication and power systems, 80% of homes, and left the country with damage costs of US$48 million. Similarly, cyclone *Evan* in 2012 and *Wilma* in 2011 left Samoa with damages costing over US$300 million (WFP and SPC 2018). The main cyclone season is November to April with activity highly correlated to the El Niño cycles. In 2014, the phase-related drought resulted in a 50% reduction in exports of squash and roots crops from Tonga (Tonga Statistics Department and Secretariat of the Pacific Community 2017; Woodfine 2019). Almost all cyclones have devastating effects on the region, prices escalate leaving the affected countries highly vulnerable and the massive destruction of critical infrastructure and agricultural land exacerbates the fragility of the food system resulting in significant food security concerns (WFP and SPC 2018).

Also, rising sea-levels have a negative impact on agriculture, fisheries and rural livelihoods. The decline in oceanic and coastal fisheries leaves both countries highly reliant on imported foods and global price fluctuations, which worsens food and nutrition security. Additionally, the rise in seawater level in Tonga could destroy the agricultural land available, and compromise its productivity through salination. The current projection indicates a rising-rate of 10mm/year or faster, which is much higher compared to the global average of 3mm/year (Tonga Statistics Department and Secretariat of the Pacific Community 2017; WFP and SPC 2018; CIA 2020).

By 2030, climate-change projections for the Pacific show a substantial increase in the occurrence of extremely hot days and nights, an increased number of heavy rain days and extreme rainfall events to occur once every seven to ten years instead of once every 20 years (Woodfine 2019). Furthermore, Samoa and Tonga will face environmental issues such as deforestation, soil erosion and exhaustion, and water pollution due to the impacts of the heavy rains, and the increased air and sea surface temperature (CIA 2020).

Drivers of change in Samoa include forest clearance, due to the increased need for agricultural land, settlements and land profiteering, which is continuing despite the efforts of the government to provide frameworks wherein all activities are screened. Additionally, fuelwood harvesting threatens the natural forest and mangrove trees further, as wood is the major source of cooking energy (FAO 2019). In Tonga, on the other hand, a reduction of agricultural biodiversity is visible, traditional crop species reduction due

to the increasing competition for land use, which continues to erode the already limited gene pool available (Vainikolo 2019). Demand for resources has increased due to the growing population, which has also led to overexploitation and destructive fishing practices, rendering the marine ecosystem even more vulnerable. Pollution and eutrophication have adversely affected Tonga's coastal waters and reefs, due to the lack of adequate sewage treatment facilities, agricultural fertilizer runoff and the waste from boats and ships. Additionally, the incursions of invasive non-local species are threatening BFA (Vainikolo 2019).

b. Mitigation strategies in production systems, for the resilience of the Pacific States

The continued use of fossil fuels as the main energy source and the rapid rates of forest loss in SIDS due to agricultural expansion and other human activities—with implications in terms of greenhouse gas (GHG) emissions—are some crucial climate-change drivers that can cause profound impacts on the local and global dynamics of terrestrial and coastal ecosystems. Therefore, climate-change mitigation strategies, encompassing human interventions at different geographical scales that can reduce the sources of GHG emissions (abatement) and/or enhance their sinks (capture) (Minister for Meteorology, Energy, Information, Disaster Management, Climate Change and Communications (MEIDECC) et al. 2019) are essential to restore and reinforce the resilience of the food system.

According to the World Resource Institute (WRI), 2017 datasets the agricultural sector ranked second in total GHG emissions, with 23% (77.4kt CO_2e) and 26.7% (195.8kt CO_2e) in Tonga and Samoa respectively. This is despite the energy sector in Tonga and Samoa (in 2017) continuing to be the largest contributing source of GHG emissions (averaging 49.4% of total emissions in both countries) (World Resource Institute (WRI) 2017). This highlights the great potential for continuing to develop and implement climate-change mitigation strategies to minimize the share of responsibility of the agricultural sector as climate change drivers. This would include other interconnected sectors such as the Land-Use Change and Forestry (LUCF) sector. Efforts will aim to maximize the aggregate benefits and synergies of implementing and scaling up sustainable agricultural practices.

SIDS' Agricultural Sector Plans 2016-2020 (Ministry of Agriculture and Fisheries (MAF) 2016a, b; Ministry of Agriculture, Food, Forests and Fisheries (MAFFF) et al. 2016) outline a common recognition of the importance of fostering climate-change adaptation and mitigation actions throughout agricultural value chains and agroecosystems. This embraces a combination of development projects—in close cooperation with a range of public and private stakeholders from the local to global scales—and actions at the policy level (IFAD 2016). In this vein, climate-change adaptation and mitigation practices approached in the sectoral plans are aligned with key objectives and expected outcomes targeted in higher-level policy documents. These include the National Determined Contributions (NDC) reports, Samoa's National Adaptation Programme of Action, and Tonga's Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management 2010-2015.

In view of the above, it is worth mentioning that such mitigation strategies and practices have the potential to generate benefits in terms of adaptive capacity and vice versa. Such practices are also diverse and can provide both direct and indirect mitigation benefits for farmers and agroecosystems, depending on the socio-environmental conditions where they are implemented. Therefore, these benefits can vary considerably between different locations and production systems (Sova et al. 2018). Compared with conventional production systems, such mitigation practices trigger changes in the different components and interactions in agricultural production systems i.e. soil, water, plants/crops, animals, energy, inputs and outputs among others (Thrall et al. 2011), fulfilling an important role in reducing GHG emissions or energy consumption and increasing carbon capture into agroecosystems' sinks.

For instance, the Land-Use Change and Forestry sector is highly interconnected with the evolution of the agricultural sector and BFA, therefore it represents a complementary mitigation window of opportunity to integrate current and promising mitigation options. In the Tongan context, efficient use of resources through protection and management of existing natural forest, by establishing management committees responsible to supervise protection and conservation initiatives, linked with proper training programmes for monitoring forest plantations are essential to keep the "green carbon" stored in the ecosystem. Likewise, promotion of agroforestry systems and/or traditional farming systems, combined with the commissioning of forest nurseries led by the private sector is vital to satisfy national demand in line with local needs, particularly by the communities, with strong women and youth engagement processes This is the case of fallow trees and non-woody species, where fast-growing, nitrogen-fixing, native species, among other similar traits, are ideal for enhancing soil fertility and carbon stock in landscape restoration and agricultural processes (e.g. *Mucuna* spp.) (Minister for Meteorology, Energy, Information, Disaster Management, Climate Change and Communications (MEIDECC) et al. 2019). Furthermore, in the Samoan context, complementary efforts point towards reforestation and community forestry programmes and envisioning the growth of a sustainable agriculture model. Including diversified and organic production systems are relevant actions not only to address underlying causes of biodiversity loss but also to meet adaptation and mitigation goals. These include initiatives for agroforestry, integrated pest management (IPM), conservation and management of genetic resources, proper water and soil management practices, and transition to renewable energy sources (Ministry of Agriculture, Food, Forests and Fisheries (MAFFF) et al. 2016; Ministry of Natural Resources and Environment (MNRE) 2016).

A significant reduction in methane emissions from enteric fermentation and manure management could be achieved in livestock systems, through improved animal nutrition (diets), along with education programmes. This would be based on strong co-design processes with farmers. They would aim to adapt existing knowledge on improved quality of livestock feed, as well as manure, crop residues, and food waste management techniques. This is exemplified by composting and biodigesters as an alternative for waste-management and organic fertilisers and energy (biogas) production at the farm and village scales (Ministry of Agriculture, Food, Forests and Fisheries (MAFFF) et al. 2016; Minister for Meteorology, Energy, Information, Disaster Management, Climate Change and Communications (MEIDECC) et al. 2019). However, continued efforts around promoting and supporting community-based management and monitoring approaches for marine resources and ecosystems are still the most viable climate-change mitigation options in the fisheries sector (Ministry of Agriculture and Fisheries (MAF) 2016b).

The contribution to climate-change mitigation goals of the above-mentioned practices—as well as others appropriate for the different stages of particular agricultural value chains (McGregor and Stice 2014)—should then be analysed from a systemic perspective to identify and quantify significant positive spill-over effects in terms of carbon capture and emissions reduction. For example, agroforestry systems or natural ecosystems conservation/restoration can sequester considerable amounts of atmospheric CO_2 in above- and below-ground biomass. It is estimated that agroforestry mitigation potential ranges from 0.29 to 15.21 t ha/year, whilst soil organic and inorganic carbon pool stores 2,300 Pg[4], which is three times the atmospheric pool (770 Pg) and 3.8 times the vegetation pool (610 Pg). This means that any agricultural practice that avoids soil disturbance and benefits its fertility, is likely to contribute to the global sequestered carbon pool (Nair et al. 2009).

On the other hand, transitioning from the conventional agricultural paradigm to local, organic, agroecological, and diversified production systems could significantly reduce the dependence on external

[4] Pg – Petagram; 1 Pg (Petagram) = 1000 million t (tonnes), i.e. 2300 Pg = 2.3 million, million t or 1 t = 1.0E-9 Pg

food and agricultural inputs such as synthetic fertilisers and pesticides, often imported to SIDS from long distances and under highly unstable commercial channels and sensitive to climatic shocks. This would thus minimize the agricultural carbon footprint, as the result of lower energy requirements and related GHG emissions from fossil fuels, during the manufacture, transport, storage, and final disposal processes of these inputs (FAO 2010; Sova et al. 2018; Savage et al. 2020). There are other potentially negative effects on the economy and human and ecosystem health (van der Velde et al. 2007; Thrall et al. 2011; Welch et al. 2019). Exploring the availability and access to Information and Communication Technologies (ICT) tools such as radio, mobiles, tablets, or multipurpose community telecentres among others, as well as innovative solutions such as "The Pacific AgriHack Lab" initiative, offers an alternative for disseminating information and engaging food-system stakeholders in agroecological farming methods around climate-change adaptation and mitigation strategies for poverty-reduction and agroecosystem health (Grunfeld and Houghton 2013; CTA and IFAD 2020).

c. Integrated pest management options

Pests and diseases in farming systems can be considered the result of an imbalance in the structure, dynamics, and general function of the agroecosystem in which they are immersed. The spatial and temporal distribution and proliferation of insect pests, weeds, and pathogens such as fungi or bacteria, is largely determined by climatic factors such as humidity, wind, light, and temperature, which in turn, influence their growth and development cycles. For example, different studies indicate that warmer temperatures can make some pest populations more active—increasing their development rates and shortening their life cycles between generations—expanding their presence to new geographical areas (Rosenzweig et al. 2001). There are also deep links of pests and diseases with sociocultural factors such as conventional on- and off-farm crop management practices and activities throughout the value chain, but particularly with those related to the farm design. When ecological elements and their interconnections are disconnected, deteriorated, or undervalued, this generates oversimplified and poorly functional farming systems with a low resilience capacity to face current and future socio-environmental implications of climate change (Altieri et al. 2015).

Cultural practices that promote farming systems' diversification are important for the long-term maintenance of soil health and fertility, and to prevent pest and disease incursions. Such practices include shifting cultivation, crop rotation, intercropping, or agroforestry systems. This situation can worsen when successive cultivation of the same species and/or botanical families occurs season after season on the farm, without integrating any crop rotation plan, even when fallow periods are reduced or non-existent due to demand for land, as in the case of SIDS (McGregor et al. 2016; Vainikolo 2019). This condition is exacerbated when conventional commercial-scale monoculture systems predominate. In addition to promoting high genetic homogenization within the landscape, monoculture can erode biodiversity through intensive management practices using external inputs and energy, or through the effects of the production model itself. Monocultures are a key factor in triggering pest outbreaks (Rosset and Altieri 1997). These threats are described in the national reports on the state of BFA of both SIDS, Tonga's Sixth National Report to the Convention on Biological Diversity (CBD) and Samoa's National Biodiversity Strategy and Action Plan (NBSAP) 2015-2020 (Thaman 2014; Ministry of Natural Resources and Environment (MNRE) 2016; FAO 2019; Minister for Meteorology, Energy, Information, Disaster Management, Climate Change and Communications (MEIDECC) et al. 2019; Vainikolo 2019)).

Cropland expansion is increasing in the SIDS. Changes in plant-insect interactions exemplify the potential consequences of climate change and variability, and land-use change. Altered precipitation and temperature patterns coupled with habitat fragmentation can disrupt phenological synchrony between

insects harmful to crops and their host plants, but also biological cycles of predators and parasitoids that act as their natural controllers. Diversification through mixed farming of multiple species and varieties of crop plants and animal breeds, as well as adopting a wide range of sustainable farm and landscape management practices is essential to maintain the resilience of agricultural production systems (Freeman 2010; Jamieson et al. 2012; McGregor et al. 2016). Therefore, a healthy agroecosystem can be promoted through management practices that involve different mechanisms such as the "disruption of spatial and temporal life cycles" of pests and diseases, fostering allelopathic effects, conservation and restoration of natural habitats and natural enemies, or by direct or indirect effects on the structure or function of the pathogen, among others (Ratnadass et al. 2012). In practical terms, Wyckhuys et al. (2020) have reported for the Asia-Pacific region that ecological control of exotic invertebrate pests, has allowed "73-100% yield-loss recovery in food, feed, and fibre crops including banana, breadfruit, cassava, and coconut" which account for a total annual recovery of in US$ 27.3 to 34.2 million and 40 to 50 million for Samoa and Tonga respectively (Wyckhuys et al. 2020).

IPM practices should also be explored and implemented, along with on-farm monitoring systems to identify permissible economic thresholds for crops in their different growth and development phases, towards timely and better-informed decision-making around sustainable pests and diseases management and control options. For promoting soil fertility as a preventive IPM strategy, practices such as green manure, composting, vermicomposting, biological nitrogen fixation (*Rhizobium* spp.), and mycorrhizal inoculation, can be accompanied by cultural and biological management practices and technologies. It is also worth highlighting the importance of permanently strengthening and updating climate information systems and networks. These use high-quality observations and resolution at island-scale, which can be accessible and sharable in an understandable way for specialised staff and farmers, in order to accurately inform IPM strategies on coastal and inland production systems. In addition, the selection of varieties resistant to pests and/or diseases, use of clean planting material, traps and natural repellents made with affordable local resources, sanitation measures, adjusted planting times and densities, among other IPM measures, are relatively well known in the region and often implemented in organic or agroecological production systems (Bell 2009; FAO 2010, 2019; Sova et al. 2018).

The above-mentioned options represent an alternative pathway to the conventional application of synthetic pesticides and even fertilizers that can otherwise negatively affect the biological and physical-chemical characteristics of the soil. Such synthetic inputs also endanger wild flora and fauna (e.g., bees, fish, and birds) and other beneficial organisms, that perform important functions in provisioning, regulating, and supporting ecosystem services such as pollination, pest and diseases regulation, soil formation, and nutrient cycling in SIDS' agricultural and natural ecosystems (Thaman 2002; FAO et al. 2016).

d. Existing research and development interventions

The Mangrove Ecosystems for Climate Change Adaptation and Livelihoods (MESCAL) project offered an interesting approach to target conservation and management of coastal mangrove ecosystems in the face of climate change while improving livelihoods of local communities in Tonga, Samoa, Fiji, Solomon Islands, and Vanuatu. Among other development objectives, the initiative actively explored opportunities to obtain carbon credits (blue carbon) for mangrove protection and reforestation, in the context of REDD+ and global carbon markets (IUCN 2020).

Under the mitigation approach, the Green Climate Fund is currently co-financing a US$ 29.2 million programme in SIDS—including Samoa and Tonga—focused on shifting from fossil fuels to renewable

energy sources. The programme not only seeks to avoid 3 million tonnes of total GHG emissions but also to strengthen energy security and improve the balance of payments through reduced fossil fuel imports. This will positively impact the agricultural sector due to its high reliance on imported diesel fuel. Under this programme, the government of Tonga is implementing the Tonga Renewable Energy Project that will deliver “utility-scale storage systems to provide baseload response and grid stability”, facilitating the integration of renewable energy, benefiting around 96,000 citizens in the country. In parallel Samoa’s government counts with a US$ 57.7 million grant for reducing vulnerability to recurrent flood-related impacts in the Vaisigano River catchment (GCF 2020).

The Global Climate-Change Alliance, along with the Secretariat of the Pacific Regional Environment Programme; the Pacific Community; Pacific Islands Forum Secretariat; and the University of the South are joining efforts in the Pacific Adaptation to Climate Change and Resilience Building project (PACRES), seeking to ensure better regional and national adaptation and mitigation responses to climate-change challenges faced by Pacific Island countries. From the six key research areas that the initiative covers, "Scaling up pilot adaptation projects" stands out, as it has included an ecosystem-based perspective for mainstreaming climate-change and disaster resilience. Other projects such as the Pacific iCLIM Phase 2 and the Climate and Oceans Support Program in the Pacific are relevant to better integrate climate information analysis and services for climate-change resilience building in the region (PCCP 2020; SPREP 2020).

Great progress has been made in generating climate-change adaptation and mitigation capacities in local communities through the Small Grant Programme of the Global Environmental Facility (GEF) administered by UNDP. For several years this initiative has supported diverse successful projects in SIDS in working areas such as biodiversity, climate-change mitigation, community-based adaptation, degraded land restoration and sustainable forest management among others with an emphasis on strengthening the agency of women and youth (GEF 2020).

From 2016 to 2020, the Agriculture Sector Growth Committee (ASGG) and the Fisheries Sector Growth Committee (FSGG) in Tonga developed the Tonga Agriculture and Fisheries sector plan with the support of the World Bank, IFAD and UNDP. The plan includes four key components: climate-resilience, agriculture and enabling environment, sustainable economic growth, and foreign exchange earnings (Ma’asi and Francis 2020). For the same time period, the government of Samoa developed the 2016–2020 agriculture sector plan, outlining four strategic policy objectives: “ensure a priority-focused agriculture sector operating within a stable and coherent enabling policy and legislative framework; ensure an increased stable supply and consumption of domestically produced nutritious food products for both rural and urban communities; enhance private-sector capacity in improving production, productivity, product quality, value-adding and marketing; and strengthen capacities in rural communities, landowners, farmers and fishers to use natural resources sustainably and increase sector resilience to natural disasters and climate change” (Ministry of Agriculture and Fisheries (MAF) 2016b).

5. Text-mining to determine evidence of mainstreamed BFA in policies in Samoa and Tonga

The text mining analysis aims to identify specific areas where cross-sector collaboration can be fostered for mainstreaming of biodiversity for food and agriculture (BFA). Our analysis identifies two key aspects common across both countries. First, there are gaps in multisectoral efforts to jointly promote sustainable production, healthy diets, and BFA for future use. For example, wider coordination of support for organic farming, agroecological approaches, and home gardens across the health, agriculture, and environment sectors can increase multiple benefits from plates and fields. Second, policies only refer to a limited number of crop and tree species. Selecting and supporting the adoption of a wide range of local or multifunctional BFA adapted to local conditions can increase the benefits of orchestrated interventions. Policies remain heavily focused on cash crops (particularly in Samoa), contributing to the neglect of other key crop and tree varieties/species for nutrition, sustainable production, and resilient farms.

a. Text mining methodology

Text was analysed from 27 and 23 legal documents from Samoa and Tonga respectively regulating aspects related to health/diets, production systems and other resources for prosperity and future use (See **Table 4** and **Table 5**). The text mining analysis helps identify to what extent the legal framework or environment enables biodiversity for food and agriculture (BFA) uptake.

Table 4 *Themes grouping the different policies, acts, regulations included in the text mining analysis where biodiversity for food and agriculture (BFA) can be mainstreamed for different goals in Samoa*

BFA for sustainable production (policy bank)	**BFA for health and diets (webpage)**	**BFA for development, climate change, risk and future use (webpage, CBD NBSAPs)**
Agriculture sector plan 2016-2020 vol. 1 and 2	Climate adaptation strategy for health	National environment sector plan 2017-2021
Agriculture and fisheries ordinance 1959	Disaster risk management: a strategy for the health sector	Pacific resilience programme: Regional environmental and social management framework
Agriculture store corporation act 1975	Integrated community health approach program survey	Protection of Samoa's traditional knowledge
Ministry of Agriculture and Fisheries (MAF) corporate plant 2016-2020	Samoan Food act 2015	Samoa national action plan for disaster risk management 2017-2021
University of the South Pacific School of agriculture act 1977 - Amendment Act 2019	Food act No. 16 arrangements of provisions	National disaster management plan 2017-2020
SAFPROM integrated pest management plan	National food and nutrition policy 2013	Water resources management act No 31 arrangement of provisions
Samoa coastal fisheries management plan 2013-2016	National non-communicable disease control policy 2018-2023	Samoa's national biodiversity strategy and action plan 2015-2020
Fisheries management act 2016		Samoa ocean strategy 2020-2030
		Samoa national invasive species strategy and action plan (NISSAP) 2019-2024
		Strategy for the development of Samoa 2016-2020
		Strengthening Climate Services in Samoa 2013-2018
		Tourism sector plan 2014-2019

Legal documents include policies, acts, plans and regulations (See **Tables 4** and **5**). Reports, scoping missions, briefs, inventories, outlooks, notices, and survey results were excluded from this analysis. Policies were grouped into three themes: BFA for production (agriculture and fisheries), BFA for health and diets (food security, health), and BFA for future use and prosperity (environment, conservation, climate resilience). Each pdf file in English was converted to text format for extracting and using sentences, words and bigrams (two consecutive words also called co-occurrences) as the units of analysis.

Table 5 *Themes grouping the different policies, acts, regulations included in the text mining analysis where biodiversity for food and agriculture (BFA) can be mainstreamed for different goals in Tonga.*

BFA in fields, rivers and sea (policy bank)	**BFA in plates / markets (webpage)**	**BFA for development, climate change, risk and future use (webpage, CBD NBSAPs)**
Corporate plan 2015-2017	Tonga framework for action on food security 2015-2020	Joint action plan for disaster risk management and climate change adaptation 2018-2028
Tonga agriculture sector plan 2016-2020	Food act 2020	Strategic development framework 2015-2025
Reinforcing effective communications in Tonga's agriculture sector	Tongan plan of action for nutrition (and annexe)	National biodiversity strategy and action plan
Tonga strategic development framework 2015-2025		Intended nationally determined contributions towards achieving the objective of UN framework convention on climate change
Aquaculture management act 2003 Amendment 2005		Forest act 2016
Tonga national aquaculture management and development plan (2014-2019)		National spatial planning and management act 2016
Pesticides act		Water resources act 2020
Tonga fisheries sector plan 2016-2024		
Fisheries management act 2016		
Agriculture commodity exports		
Disease of plant regulations 2016		
Agriculture commodities export Act 2016		
Pesticides act 2016		

The R packages pdftools, tm, and tidytext were used (Silge and Robinson 2016; Feinerer and Hornik 2019; Ooms 2020; R Core Team 2020). The text was cleaned through three methods: first, removal of empty lines, horizontal and vertical tabs, and non-word characters using the metacharacters in the stringr package (Wickham 2019); second, removal of standard stop words listed in tidytext; and third, creation (and removal from the text) of a list of stop words through an iterative process of looking at the words and sentences (e.g. page, title, act, policy, Samoa, Tonga). Co-occurrences were calculated of the "term frequency -tf" in each policy and the "inverse document frequency-idf" (logarithm of the ratio between the number of legal documents per theme and the number of documents where the co-occurrences appear). Tf helps identify the most common co-occurrences and tf*idf the co-occurrences unique to each theme.

The Snowball algorithm in the tm package was used to identify word stems for calculating the common words in the legislation across sectors regardless of the conjugation and for finding BFA-related words from a pre-defined list of concepts and keywords. The concepts/keywords identified and developed by the Agrobiodiversity Index were used and complemented with locally relevant literature to identify BFA mentions linked to sustainable production, nutritious diets, and conservation and future use (See Appendix A).

b. The legal landscape for fostering diversified and nutritious diets, sustainable diverse and resilient production system in Samoa

Samoan text mining analysis (see **Table 2** and section a) for method) indicates that multiple sectors share and express a common concern around climate change. Similarly, BFA for production and future use mentions the private sector and BFA for future use and diets mention disaster risk quite often (**Figure 5**).

In Samoa, policies seem to recognize the role of "cross-sectoral" (17 mentions across policies) efforts for concerted action. Other concepts, however, such as "integrated approaches" (four), "integrated management" (three), "partner coordination" (zero), "partner coordination" (zero), "partner collaboration" (zero), "sector collaboration" (one) were mentioned rarely despite the importance of adopting these concepts for achieving global targets to end malnutrition in all its forms (WHO 2020).

Overall, fruits and vegetables are often mentioned across themes. Nonetheless, important aspects for sustainable food systems such as "nutrition-sensitive", "nutrition-specific", "nutrition targets", "non-trade distorting", "nutrient-rich" measures, or "water stress" (highlighted in (FAO et al. 2017)) are missing (**Figure 5, and Figure 6**).

A closer look at the different practices or interventions where BFA can be mainstreamed also indicates key areas for policy alignment and multisectoral collaboration. For example, BFA policies for production mention local foods, nutritious foods, and domestic foods more often than other themes' policies despite the importance of local foods in nutrition security (**Figure 6**). Hence, Ministries of Health, Natural Resources & Environment, and Agriculture & Fisheries can better articulate efforts and investments on interventions that increase organic farming for local consumption and agroforestry systems for food security. Interestingly, only mentions of practices that contribute to sustainable agriculture and nutritional outcomes were found (e.g. agrobiodiversity, home gardens, pollinators, underutilized crop, agricultural diversity and multiple crops) in BFA policies for prosperity and the future.

Key seed-nursery related concepts are missing from the analysed documents, including local seed diversity, seed banks, or seed/planting material availability (**Figure 6**). Protecting landraces as well as having access to locally adapted seeds, planting material and breeds is critical for designing resilient farming and fishing systems adapted to the changing climate.

Organic agriculture is more commonly mentioned than climate-smart agriculture or agroecological practices (**Figure 6**). This is in line with the recognition of organic agriculture as a strategy to achieve multiple outcomes including enhanced health, ecosystem services, income, food security, climate-change mitigation and fragile ecosystems protection in the region (FAO et al. 2016). Support to increase the adoption of these alternatives, sustainable and resilient production systems could be orchestrated across sectors for selecting species and practices that contribute to local farmers' nutrition, income, and resilience. Samoa is leading initiatives on integrated pest management with natural enemies, habitat management, minimal pesticide applications through farmer field schools according to FAO (2016), which is in line with a large number of mentions in BFA for production policies.

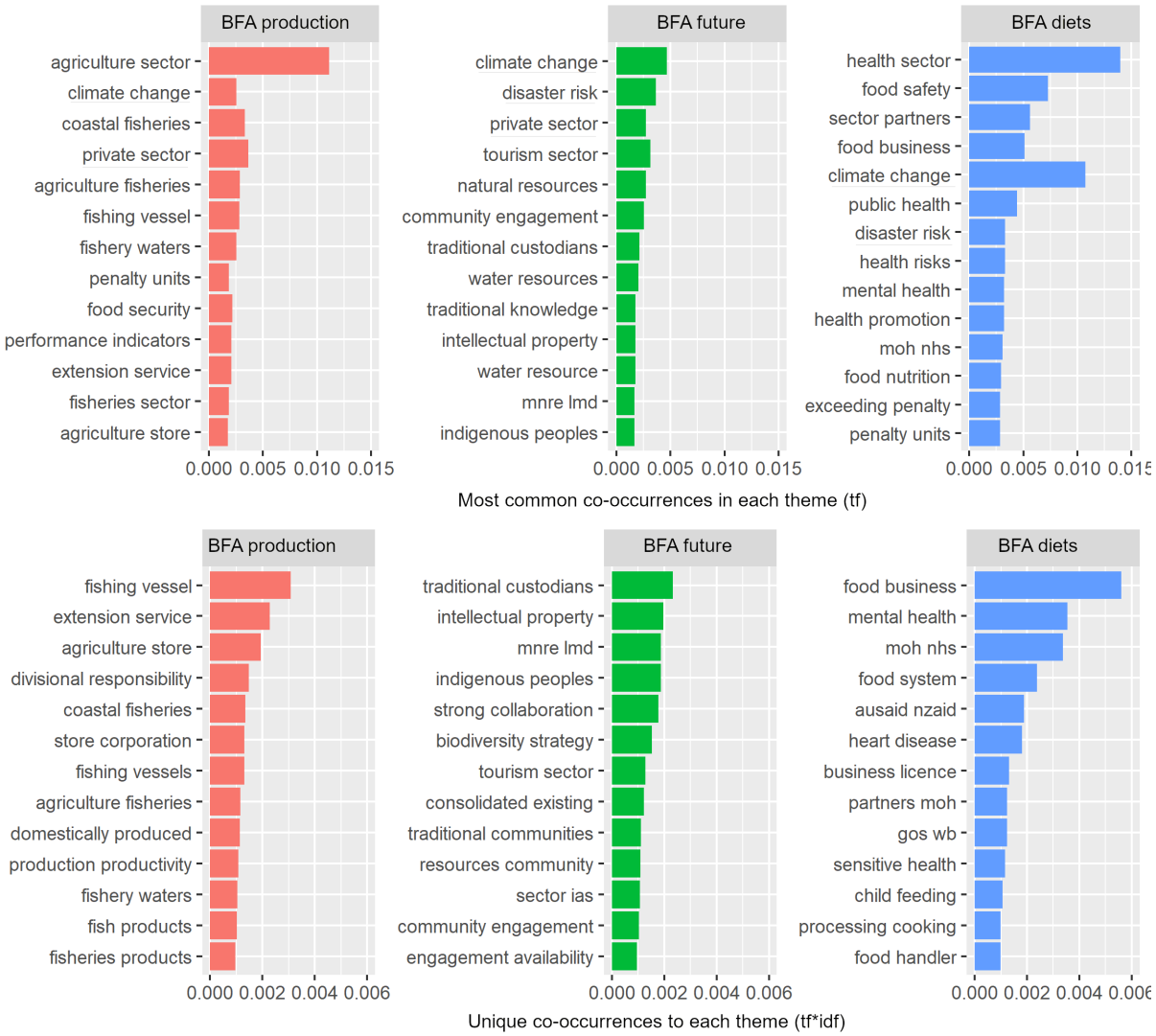


Figure 5 *Most common (term frequency -tf) and unique (TF*IDF score) co-occurrences found in the legal document per and across regulating themes, including BFA for sustainable production, BFA for prosperity and future use and BFA for nutritious and healthy diets.* *Moh nhs=Ministry of Health national health services; mnr lmd=ministry of natural resources and environmental land management division; sector ias=sectors implementing agencies; ausaid=Australian AID; nzaid=New Zealand AID; gos wb= Government of Samoa World Bank.*

Mobilizing the local crop and tree diversity is an untapped resource. Various reports identified already useful plants/crops/trees that can contribute to nutrition and the resilience of the Pacific's productive systems (Taylor et al., 2009; FAO 2016; MOH). In total, over 200 crop species were listed in the food composition table for the Pacific (Dignan and FAO 2004), plants of the future (Taylor et al. 2009), star trees of life (FAO et al. 2016) and green vegetables MOH. Only 35 crops are mentioned, and taro, tobacco and coconut share 44% of the mentions (**Figure 7**). Only two crops (classified as green leaves) listed and recommended by the Ministry of Health are also present in the Ministry of Agriculture legislation (chilli, pumpkin). Regarding trees, mentions for only 17 species were found, of which coconut, pua (*Fagraea berteroana*) and lime share 62% of the mentions. Orchestrated interventions and collaborations across sectors can help identify locally adapted, resilient, and nutritious crops/trees and support farmers' adoption.

Theme	BFA related concept	BFA production	BFA future	BFA diets
Diet (mentions 78)	local foods	22	1	10
	nutritious food	19		4
	domestic foods	13	3	
	healthy foods	1		13
	dietary guidelines			3
	food diversity	1	1	
	balanced diet			1
	edible plants		1	
	food variety			1
	nutritional quality			1
	nutritious crops			1
	nutritious diets			1
	organic products	1		
Future (mentions 19)	plant breeder		47	
	domestication animals		16	
	exsitu conservation		16	
	animal w ild relative		11	
	insitu conservation		5	
	plant accessions		5	
Production (mentions 238)	integrated pest management	36	1	
	organic farming	6	4	
	agroforestry	3	5	
	agrobiodiversity		5	
	organic products	3	1	
	planting material	3	0	
	biopesticides	2	0	
	fisheries conservation	1	1	
	natural enemies	2		
	livestock breed	2		
	traditional crop	2		
	crop rotation	1		
	cultivated plants		1	
	home gardens		1	0
	local fish	1	0	
	pollinators	0	1	
	riparian corridors		1	
	underutilized crop		1	
	agricultural diversity		1	
	agroecological	0	0	
	crop diversity	0	0	
	mixed cropping	0	0	
	multiple crops		1	
	organic agriculture	0	0	
	organic production	0	0	
	tree crops	0	0	
	beneficial insects	0		
	boundary planting		0	
	climate smart agriculture	0		
	cover crops	0		
	cultivars	0		
	cultivated fish		0	
	diversity agroecosystems	0		
	farmed species	0		
	fish diversity		0	
	habitat diversity	0		
	habitat retention		0	
	indigenous crops			0
	integrated cropping	0		
	livestock diversity		0	
	livestock varieties		0	
	local breed		0	
	productive trees		0	
	riparian vegetation		0	
	traditional fisheries	0		

Figure 6 *Mentions of BFA related concepts in the legal documents analysed across themes. Values add to 100% per theme. Concepts adopted from the Agrobiodiversity Index.*

Food groups	Food tree/crops	BFA production	BFA future	BFA diets
Fruits (mentions 61)	citrus	0	0	
	coconut	6	4	1
	grape	0		
	lime	0	2	2
	lychee		0	
	mango		0	
	mangosteen		0	
	orange		0	0
	papaya		0	
	plum		4	0
	rambutan		1	
	starfruit		0	
	tava	0	1	
Stimulant (mentions 46)	cocoa	5	3	
	coffee	0	0	
	tobacco	0	1	12
Green leaves, starchy staples (mentions 36)	taro	6	11	0
Other vegetables (mentions 18)	capsicum	1		
	carrot	0		
	corn	0		0
	cucumber	1		
	eggplant	0		
	olive		1	
	onion	0		
	tomato	3		
Green leaves (mentions 16)	cabbage	6		
	fern		0	
	lettuce	0		
	mulberry		0	
Starchy staples, fruits (mentions 13)	banana	5	1	0
Nuts and seeds, starchy staples (mentions 5)	breadfruit	2	0	
Nuts and seeds (mentions 4)	pili		2	
Green leaves, nuts and seeds, other vegetables (mentions 1)	pumpkin	0		
Legumes (mentions 1)	beans	0		
Starchy staples (mentions 1)	potato	0		
Multifunctional trees	**Trees**	**BFA production**	**BFA future**	**BFA diets**
"Superstar" multipurpose trees (mentions 37)	banana	3	1	1
	beach mulberry		1	
	breadfruit	5	1	
	coconut	18	12	4
	common bamboo		1	
	noni	1		
Widespread - great importance tree species (mentions 23)	bele	1		3
	fiji sandalw ood		1	
	kava	4	1	
	mango		1	
	orange		1	1
	papaya		1	
	poumuli		1	
	pua	1	8	4
Important - considerable important tree species (mentions 14)	coffee	1	1	
	crepe jasmine		1	
	lime	1	7	7

Figure 7 *Multifunctional and nutritious crops mentioned in legislation where BFA can contribute to 1) sustainable production, 2) health and diets and 3) prosperity and future use.*

c. The legal landscape for fostering diversified and nutritious diets, sustainable diverse and resilient production systems in Tonga

Tongan text mining analysis (see Table 1 and section a) for methods) indicates that multiple sectors share and express a common concern around climate change (**Figure 8**). Similarly, policies deploying BFA for production and diets tend to mention food security quite frequently. On the other hand, policies across the three themes tend to mention different sectors like the private sector in BFA for production, civil society, and local communities in BFA for future use, and corporate bodies in BFA for healthy diets. In general, policies promoting BFA in production focus on improving knowledge indicators, agriculture, aquaculture, and other types of fishing. BFA for future use focuses on outcomes, inclusiveness, priority

species, and measurements. Finally, food regulation mentions dominating BFA in diets legal documents (**Figure 8**).

In Tonga, "integrated approaches" (15) or, "integrated management" (two)" was found across policies. Although other concepts such as "cross-sectoral" (one), "partner coordination" (zero), “partner collaboration” (zero) and “sector collaboration (one)" were rarely mentioned despite the importance of adopting these concepts for achieving global targets to end malnutrition in all its forms (WHO 2020a).

Overall, fruits and vegetables are often mentioned across themes. Nonetheless, important aspects for sustainable food systems such as "nutrition-sensitive", "nutrition-specific", "nutrition targets", "non-trade distorting", "nutrient-rich" measures, or "water stress" (highlighted in FAO 2017a) are missing (**Figure 8, and Figure 9**).

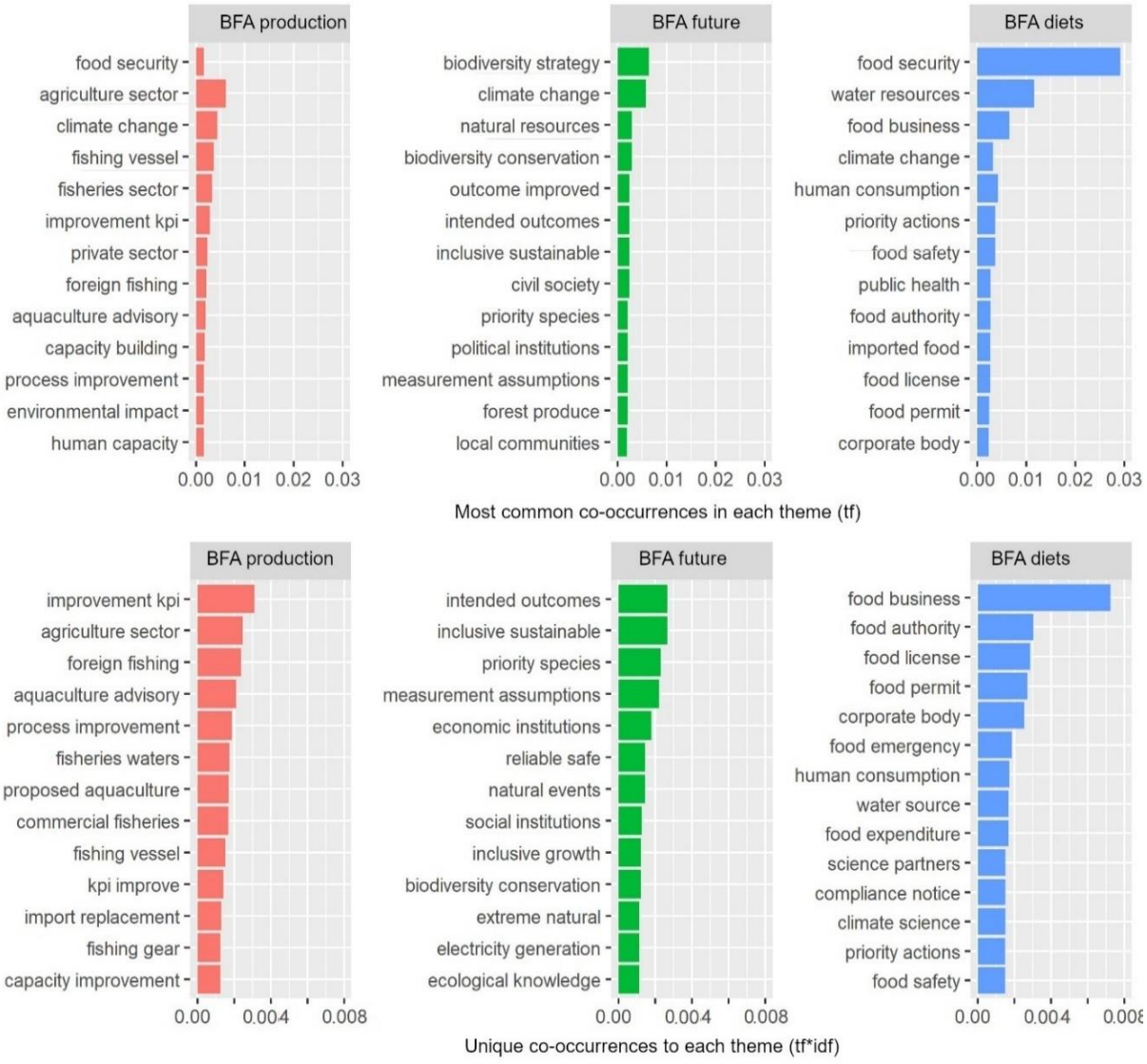


Figure 8 *Most common (term frequency -tf) and unique (TF*IDF score) co-occurrences found in the legal documents per and across regulating themes, including BFA for sustainable production, BFA for prosperity and future use, and BFA for nutritious and healthy diets.* *Kpi=key performance indicators*

A closer look at the different practices or interventions where BFA can be mainstreamed also indicates key areas for policy alignment and multisectoral collaboration (**Figure 9**). For example, both BFA for production and BFA for healthy diets mention in a similar proportion of local foods. Other terms related to nutrition

security such as seasonal food, indigenous food, and diversified foods are more mentioned by BFA in production. In contrast, BFA in nutrition uses other terms, such as functional foods and nutritious food (**Figure 9**). Overall, healthy foods were the more mentioned term by BFA for production.

Mentions related to BFA for future use remain scarce in the analysed policies (**Figure 9**). However, terms related to BFA in production were quite common, including 52 different concepts. Agrobiodiversity (12% of the mentions), agroforestry (10%), local fish (9%), integrated pest management [IPM] (6%), and diversity farm (6%) share half of the mentions across the analysed policies.

Overall, legal documents from the three themes rarely mention organic products, production, farming, certification, conservation agriculture, climate-smart agriculture or agroecological practices. Hence, Ministries of Health, Natural Resources & Environment, and Agriculture & Fisheries can better articulate efforts and investments on interventions that increase the adoption of these sustainable agriculture production methods, in particular organic farming for local and diversified consumption.

Mobilizing the local crop and tree diversity is an under-tapped resource. Various reports identified already useful plants/crops/trees that can contribute to nutrition and the resilience of the Pacific's productive systems (Taylor et al. 2009; FAO et al. 2016) (MOH). In total, over 200 crop species were found listed in the food composition table for the Pacific (Dignan and FAO 2004), plants of the future (Taylor et al. 2009), start trees of life (FAO et al. 2016) and green vegetables by Samoan MOH. Only 39 crops are mentioned, of which coconut, cucumber and squash share 34% of the mentions (Figure 10). Regarding trees, mentions for only 32 species were found, with coconut, lime and kava sharing 41% of the mentions (Figure 10). Orchestrated interventions and collaborations across sectors can help identify locally-adapted, resilient, and nutritious crops/trees and support farmers' adoption.

Theme	BFA related concept	BFA production	BFA future	BFA diets
Diet (mentions 51)	diet diversity			2
	dietary guidelines			4
	diversity foods	2		
	functional foods			8
	healthy foods	37		6
	indigenous food	2		
	local foods	14		12
	nutritional quality			2
	nutritious food	2		8
	seasonal food	2		
Future (mentions 5)	accessions plants	2		
	domestication animals	2	2	
	domestication plants	2		
	exsitu conservation		2	
Production (mentions 236	agricultural biodiversity	1	0	
	agricultural plants	0		
	agrobiodiversity	0	11	
	agroecological	2		
	agroforestry	2	4	4
	artisanal fishing	1	0	
	climate smart agriculture			1
	conservation agriculture	1		
	conservation fisheries	0	0	
	cover crops	0		
	crop diversity	3		2
	cultivars	0		
	cultivated fish	1		
	cultivated varieties		1	
	diversity farms	6	0	
	diversity fish		0	
	domestic livestock	1		
	domestication fish	1		
	enrichment planting	2		
	fallow land			0
	farm diversity	0		
	farmed species	0		
	fish domestication	1		0
	fisheries conservation	2	0	0
	fisheries diversity	0		
	habitat diversity		0	
	home gardens	2		
	indigenous crops			1
	indigenous fish	0		
	integrated aquaculture	0		
	integrated cropping	3		
	ipm	8		
	livestock breed			1
	livestock diversity	2		
	local breed			0
	local fish	9		0
	mixed cropping	1	0	1
	mixed farming		1	1
	multispecies fisheries	0		
	organic agriculture	0		1
	organic certification	0		
	organic farming	1	1	0
	organic production	0		
	organic products	0		
	planting material	3	0	0
	production diversity	2		
	productive trees	0		
	soil biodiversity	1		
	soil protection	0	0	
	traditional crop		0	1
	tree crops		0	

Figure 9 *Mentions of BFA related concepts in the legal documents analysed across themes. Values add to 100% per theme. Concepts adopted from the Agrobiodiversity Index.*

Food groups	Food tree/crops	BFA production	BFA future	BFA diets
Fruits (mentions 68)	apple	2		
	avocado			0
	citrus		2	0
	coconut	10	2	1
	guava			0
	lime	3		3
	mango			1
	papaya	0		0
	plum	0		
	tava	0	3	
Green leaves (mentions 6)	fern		1	
	hibiscus		0	
	mulberry	1		0
Green leaves, nuts and seeds, other vegetables (mentions 2)	pumpkin	1		
Green leaves, starchy staples (mentions 19)	cassava	1	0	2
	sweet potato	1	0	
	taro	1	0	2
Legumes (mentions 1)	beans	3		0
Nuts and seeds (mentions 7)	pili	1	2	
Nuts and seeds, fruits (mentions 14)	melon	3		0
	watermelon	3		0
Nuts and seeds, fruits, starchy staples (mentions 3)	pandanus	1	0	
Nuts and seeds, starchy staples (mentions 7)	breadfruit	2		1
Other vegetables (mentions 74)	brussels	2		
	capsicum	0		
	corn	1		
	cucumber	10	1	
	fungi	1		
	mushrooms	0		
	onion	3		
	squash	7		3
	tomato	3		
	zucchini	0		
Starchy staples (mentions 16)	potato	3	0	0
	yam		0	2
Starchy staples, fruits (mentions 4)	banana			2
Stimulant (mentions 9)	cocoa			0
	coffee	0		
	tobacco	1	0	2
Multifunctional trees	**Trees**	**BFA production**	**BFA future**	**BFA diets**
"Superstar" multipurpose trees (mentions 54)	banana			1
	beach hibiscus		1	
	beach mulberry	2		1
	breadfruit	3		2
	coconut	19	3	2
	common bamboo		1	
	noni	5		
	pandanus	2	1	
Widespread - great importance tree species (mentions 48)	beach cordia	1		1
	cassava	2	1	3
	fiji sandalwood	3	1	2
	guava			1
	kava	4	2	2
	koka		2	
	leucaena	2		
	mango			2
	manioc	1	1	1
	papaya	1		1
	paper mulberry			1
	pua	4	2	
	tapioca		1	
Important - considerable important tree species (mentions 26)	avocado			1
	barringtonia		2	
	coffee	1		
	eucalyptus		1	
	langakali		2	
	lime	5		5
	neisosperma		1	
	oil palm	1		
	pipturus		1	
	premna		1	
	teak	1		

Figure 10 *Multifunctional and nutritious crops mentioned in legislation where BFA can contribute to 1) sustainable production, 2) health and diets and 3) prosperity and future use.*

6. *The food systems framework considering the nexus of food and nutrition security, climate change and biodiversity for food and agriculture*

The food system is very complex, which needs multi-sectoral thinking and collaboration. Additionally, the Pacific Islands current food systems are highly vulnerable to extreme events. Both Samoa and Tonga are prone to natural disasters, such as cyclones, flash floods, and earthquakes (FAO 2019; FAO and Commission on Genetic Resources for Food and Agriculture 2019). Tonga is ranked the second most at-risk country in the world to natural hazards. Similarly, cyclones Evan in 2012 and Wilma in 2011 left Samoa with damages costing over US$300 million (WFP and SPC 2018). While natural hazards and disasters have an immediate effect on agricultural production, they also affect food product imports, increasing prices and food scarcity (Troubat et al. 2020). The increased prices leave the countries highly vulnerable. Massive destruction of critical infrastructure and agricultural land significantly affects the fragile food system, which results in significant food security concerns (WFP & SPC 2018).

Also, rising sea-levels have a negative impact on agriculture, fisheries and rural livelihoods. The decline in oceanic and coastal fisheries leaves both Samoa and Tonga highly reliant on imported foods and global price fluctuations, which worsens food and nutrition security. These environmental, economic and eventually livelihoods impact of climate change-related issues not only reveal the fragility of the conventional food systems but also demonstrate the opportunity for integrating ecologically sound management strategies to enhance climate resilience and climate-change mitigation capacities in the food system.

The text mining analysis also showed that policies hardly mention crop and tree species diversity, which could play a central role in increasing the local and traditional species and varieties, particularly after dismantling perceptions that associate them with poverty or low status (Englberger 2011; FAO et al. 2017). Local varieties are generally nutrient-rich (Englberger 2011), and interventions such as backyard gardens in urban and rural settings can contribute a significant amount of vegetables and enhance the consumption of nutritious, unprocessed and fresh foods, boosting healthier diets and self-reliance (FAO et al. 2017; Win Tin et al. 2020). The legal document search, for example, identified fruits and vegetables across themes, but the meaning and important aspects for sustainable food systems are missing. To increase the importance of the aspects of nutrition-specific, and nutrition-sensitive interventions need to be understood across all sectors. Through the same text mining analysis, gaps were identified in multisectoral efforts for promoting the biodiversity of food and agriculture. Addressing these gaps will be key for better coordination and bridging efforts towards the same goal.

Through the review and text-mining exercise, we identified that there are no current multi-sectoral collaborations in Samoa and Tonga, which are needed for better coordination and bridging efforts towards sustainable and resilient food systems. In the next steps through key informant interviews and focus group discussions, we want to further identify where cross-sectoral collaboration already exists and how they work will be gathered to get a better understanding to aid cooperation on successful strategies and synergies regarding agrobiodiversity for food and agriculture. This will inform us which collaboration systems we need to foster and support.

7. Recommendations

Cross-sector collaborations are key for developing sustainable food systems, as well as to ensure that the nexus of BFA, farming systems, food and nutrition security and climate-change adaptation is strengthened to dynamize livelihoods and ecosystem services. Through the identification of the existing landscape and gaps, the following next steps have crystalized:

- Build, foster and support multi-sectoral (health, agriculture, environment, education) collaborations, which are needed for better coordination and bridging efforts towards the same goal. The results from the key informant interviews and focus group discussions planned can be used to identify successful and potential collaborations regarding BFA and will enhance the understanding of the nexus on BFA, food and nutrition security, and climate change and foster collective action for projects towards sustainable and resilient food systems.
- Revision of policies to include the meaning and importance of nutrition-specific, and nutrition-sensitive interventions across sectors, including the promotion of a range of food items, especially fish, seafood and fruits, vegetables from both crop and tree species. Current policies remain heavily focused on cash crops (particularly in Samoa), contributing to neglected key crop and tree varieties/species for nutrition, sustainable production, and resilient farms.

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Appendix A. Search terms from the Agrobiodiversity Index to capture key concepts related to agrobiodiversity.

Sub-theme	Theme	Concept unified	Concepts
Access	Future	accessions characterized	cultivated accessions characterized
Access	Future	accessions evaluated	cultivated accessions evaluated
Access	Future	community seed bank	community seed bank
Access	Future	germplasm characterization	germplasm characterization
Access	Future	germplasm evaluation	evaluation germplasm
Access	Future	germplasm evaluation	germplasm evaluation
Access	Future	plant accessions	accessions plants
Access	Future	plant accessions	plant accessions
Access	Future	seed bank diversity	diversity seed banks
Access	Future	seed bank diversity	seed bank diversity
Access	Future	seed genetic diversity	seed genetic diversity
Access	Production	local seed bank	local seed bank
Access	Production	planting material	planting material
Access	Production	seed availability	seed availability
Access	Production	seed information system	seed information system
Access	Production	seed market	formal seed market
Access	Production	seed market	informal seed market
Access	Production	seed market	seed market
Access	Production	seed system	formal seed system
Access	Production	seed system	informal seed system
Access	Production	seed system	seed system
Animal			fish
Animal			livestock
Animal			poultry
conservation	reproduction		breeding
conservation	reproduction		genetic
conservation	reproduction		germplasm
conservation	reproduction		nurseries
conservation	reproduction		seed
conservation	reproduction		semen
conservation	reproduction		tissue
Diets	Diet	balanced diet	balanced diet
Diets	Diet	dietary guidelines	diet diversity score
Diets	Diet	dietary guidelines	diet guidelines
Diets	Diet	dietary guidelines	dietary guidelines
Diets	Diet	dietary guidelines	plant-based diet
Diets	Diet	food composition table	food composition table
Diets	Diet	healthy foods	healthy foods
Diets	Diet	nutritional quality	nutritional quality
Diets	Diet	nutritious crops	nutritious crops
Diets	Diet	nutritious diets	nutritious diets
Diets	Diet	organic products	organic supply
Diversity	Diet	available diversified foods	diversified foods

Sub-theme	Theme	Concept unified	Concepts
Diversity	Diet	diet diversity	diet diversity
Diversity	Diet	diet diversity	diversified diets
Diversity	Diet	edible animals	edible animals
Diversity	Diet	edible fungi	edible fungi
Diversity	Diet	edible insects	edible insects
Diversity	Diet	edible plants	edible plants
Diversity	Diet	food diversity	diversity foods
Diversity	Diet	food diversity	food diversity
Diversity	Diet	food group diversity	food group diversity
Diversity	Diet	food group diversity	food groups
Diversity	Diet	food variety	food variety
Diversity	Diet	food variety	variety of foods
Diversity	Diet	functional foods	functional foods
Diversity	Diet	nutrition diversity	nutrition diversity
Diversity	Diet	nutritional functional diversity	nutritional functional diversity
Diversity	Diet	nutritious crops	nutritious indigenous
Diversity	Diet	nutritious food	nutritious food
Diversity	Diet	nutritious fungi	nutritious fungi
Diversity	Diet	nutritious insects	nutritious insects
Diversity	Diet	seasonal food	seasonal food
Diversity	Future	base-broadening	base-broadening breeding
Diversity	Future	breed diversification	breed diversification
Diversity	Future	breed diversification	diversity breeds
Diversity	Future	crop gene bank diversity	crop gene bank
Diversity	Future	ex-situ diversity	ex situ diversity
Diversity	Future	ex-situ diversity	ex situ diversity
Diversity	Future	fish genetic diversity	fish genetic diversity
Diversity	Future	germplasm diversity	diversity germplasm
Diversity	Future	germplasm diversity	germplasm diversity
Diversity	Future	insitu diversity	in situ diversity
Diversity	Future	insitu diversity	insitu diversity
Diversity	Future	livestock semen diversity	livestock semen diversity
Diversity	Production	agricultural biological diversity	agricultural biological diversity
Diversity	Production	agricultural diversity	agricultural biodiversity
Diversity	Production	agricultural diversity	agricultural diversity
Diversity	Production	agricultural plants	agricultural plants
Diversity	Production	agricultural species	agricultural species
Diversity	Production	Agrobiodiversity	agrobiodiversity
Diversity	Production	Agroforestry	agroforestry
Diversity	Production	Agroforestry	agroforestry
Diversity	Production	animal breed	animal breed
Diversity	Production	animal breed	breed animals
Diversity	Production	aquaculture multispecies	aquaculture multispecies
Diversity	Production	boundary planting	boundary planting
Diversity	Production	boundary planting	crop border

Sub-theme	Theme	Concept unified	Concepts
Diversity	Production	boundary planting	planting boundaries
Diversity	Production	companion crops	companion crops
Diversity	Production	cover crops	cover crops
Diversity	Production	crop associations	crop associations
Diversity	Production	crop diversity	crop diversity
Diversity	Production	crop diversity	diversity crops
Diversity	Production	crop-rotation	crop-rotation
Diversity	Production	crop-rotation	rotation crops
Diversity	Production	crop species diversity	crop species diversity
Diversity	Production	crop species diversity	diversity crop species
Diversity	Production	crop variety diversity	crop variety diversity
Diversity	Production	Cultivars	cultivars
Diversity	Production	cultivate nutritious crops	cultivate nutritious crops
Diversity	Production	cultivated fish	cultivated fish
Diversity	Production	cultivated plants	cultivated plants
Diversity	Production	cultivated species	cultivated species
Diversity	Production	cultivated varieties	cultivated varieties
Diversity	Production	cultivated varieties	varieties cultivated
Diversity	Production	diverse landscape	diverse landscape
Diversity	Production	diverse landscape	diversified landscape
Diversity	Production	diverse landscape	landscape diversity
Diversity	Production	diverse seascape	diverse seascape
Diversity	Production	diverse seascape	diversified seascape
Diversity	Production	diverse seascape	seascape diversity
Diversity	Production	diverse seed variety	diverse seed variety
Diversity	Production	diversity agroecosystems	agroecosystems diversity
Diversity	Production	diversity agroecosystems	agroecosystems diversity
Diversity	Production	diversity agroecosystems	diversity agroecosystems
Diversity	Production	diversity agroecosystems	diversity agroecosystems
Diversity	Production	ecological connectivity	ecological connectivity
Diversity	Production	enrichment planting	enrichment planting
Diversity	Production	farm crop variety	farm crop variety
Diversity	Production	farm diversity	diversity farms
Diversity	Production	farm diversity	farm diversity
Diversity	Production	farmed fish diversity	farmed fish diversity
Diversity	Production	farmed species	farmed species
Diversity	Production	farmer breeds	breeds farmers
Diversity	Production	farmer breeds	farmer breeds
Diversity	Production	farmer variety	farmer variety
Diversity	Production	farmer variety	varieties of farmers
Diversity	Production	fish diversity	diversity fish
Diversity	Production	fish diversity	fish diversity
Diversity	Production	fishpond polyculture	fishpond polyculture
Diversity	Production	grass strips	grass strips
Diversity	Production	grass strips	grass strips

Sub-theme	Theme	Concept unified	Concepts
Diversity	Production	grazing species diversity	grazing species diversity
Diversity	Production	habitat connectivity	connectivity habitat
Diversity	Production	habitat connectivity	habitat connectivity
Diversity	Production	habitat conservation	conservation habitat
Diversity	Production	habitat corridors	corridors habitats
Diversity	Production	habitat corridors	habitat corridors
Diversity	Production	habitat diversity	diversity habitats
Diversity	Production	habitat diversity	habitat diversity
Diversity	Production	habitat retention	habitat retention
Diversity	Production	habitat retention	retention habitat
Diversity	Production	hedges diversity	hedges diversity
Diversity	Production	hedges diversity	hedges length
Diversity	Production	heterogeneous landscape	heterogeneous landscape
Diversity	Production	heterogeneous landscape	landscape heterogeneity
Diversity	Production	heterogeneous seascape	heterogeneous seascape
Diversity	Production	heterogeneous seascape	seascape heterogeneity
Diversity	Production	home gardens	backyard gardens
Diversity	Production	home gardens	domestic gardens
Diversity	Production	home gardens	home gardens
Diversity	Production	home gardens	kitchen gardens
Diversity	Production	home gardens	vegetable gardens
Diversity	Production	Intercropping	intercropping
Diversity	Production	Intercropping	intercropping
Diversity	Production	livestock breed	breeds livestock
Diversity	Production	livestock breed	livestock breed
Diversity	Production	livestock diversity	diversity livestock
Diversity	Production	livestock diversity	livestock diversity
Diversity	Production	livestock varieties	livestock varieties
Diversity	Production	livestock varieties	varieties livestock
Diversity	Production	multiple crops	multiple crops
Diversity	Production	multispecies fisheries	fisheries diversity
Diversity	Production	multispecies fisheries	multispecies fisheries
Diversity	Production	Pollinators	pollinators
Diversity	Production	Polycultures	polycultures
Diversity	Production	Polycultures	polycultures
Diversity	Production	poultry breed	breeds poultry
Diversity	Production	poultry breed	poultry breed
Diversity	Production	poultry diversity	diversity poultry
Diversity	Production	poultry diversity	poultry diversity
Diversity	Production	production diversity	production diversity
Diversity	Production	productive trees	productive trees
Diversity	Production	riparian corridors	riparian corridors
Diversity	Production	riparian corridors	riparian zone
Diversity	Production	riparian vegetation	riparian vegetation
Diversity	Production	rotational pasture	rotational pasture

Sub-theme	Theme	Concept unified	Concepts
Diversity	Production	seascape complexity	seascape complexity
Diversity	Production	semi-natural habitat	semi-natural habitat
Diversity	Production	semi-natural habitat	seminatural habitat
Diversity	Production	set aside	set aside
Diversity	Production	shrubs hedgerows	shrubs hedgerows
Diversity	Production	shrubs vegetated field boundaries	field boundaries
Diversity	Production	Silviculture	silvi culture
Diversity	Production	Silviculture	silviculture
Diversity	Production	Silvopasture	silvo pasture
Diversity	Production	Silvopasture	silvopasture
Diversity	Production	species functional diversity	species functional diversity
Diversity	Production	strip flowers	flower strips
Diversity	Production	strip flowers	strip flower
Diversity	Production	tree crops	tree crops
Diversity	Production	trees/wildflowers/shrubs field margins	field margins
Diversity	Production	used varieties	used varieties
Diversity	Production	varietal diversity	varietal diversity
Diversity	Production	varietal diversity	varietal diversity
Diversity	Production	Windbreaks	windbreaks
Diversity	Production	woodland patches	woodland patches
Diversity	Production	woodland patches	woodland patches
Food access			food affordability
Food access			food availability
Food access			fresh foods
Food access			fresh supply
Food access			safe food
Food access			seasonal foods
Food/crop types			cattle
Food/crop types			chicken
Food/crop types			citrus
Food/crop types			fruit tree
Food/crop types			fruits
Food/crop types			greengrass
Food/crop types			stapple
Food/crop types			tilapia
Food/crop types			tubers
Food/crop types			vegetables
Future	Future	aquatic genetic resources	aquatic genetic resources
Future	Future	crop breeder	breeder crops
Future	Future	crop breeder	crop breeder
Future	Future	crop tissue diversity	crop tissue diversity
Future	Future	cryoconservation animal	cryoconservation animal
Future	Future	cryopreservation fish	cryopreservation fish
Future	Future	cryopreservation gametes	cryopreservation gametes
Future	Future	cultivar breeder	cultivar breeder

Sub-theme	Theme	Concept unified	Concepts
Future	Future	domestication animals	animals domestication
Future	Future	domestication animals	domestication animals
Future	Future	exsitu conservation	ex situ conservation
Future	Future	exsitu conservation	exsitu conservation
Future	Future	farm breeder	farm breeder
Future	Future	fish breeder	breeder fish
Future	Future	fish breeder	fish breeder
Future	Future	in situ conservation	in situ conservation
Future	Future	in situ conservation	in situ conservation
Future	Future	livestock breeder	breeder livestock
Future	Future	livestock breeder	livestock breeder
Future	Future	plant breeder	breeder plants
Future	Future	plant breeder	plant breeder
Future	Future	plant domestication	domestication plants
Future	Future	plant domestication	plant domestication
Future	Future	poultry breeder	breeder poultry
Future	Future	poultry breeder	poultry breeder
Future	Future	poultry breeding	breeder poultry
Future	Future	poultry breeding	poultry breeder
Future	Future	tree breeder	breeder trees
Future	Future	tree breeder	tree breeder
Future	Production	crop seed diversity	crop seed diversity
Future	Production	fish domestication	domestication fish
Future	Production	fish domestication	fish domestication
healthy diets			NCD
Local	Diet	domestic foods	domestic foods
Local	Diet	indigenous food	indigenous food
Local	Diet	local diet	local diet
Local	Diet	local foods	local foods
Local	Diet	neglected food	neglected foods
Local	Diet	underutilized food	underutilized foods
Local	Diet	underutilized food	underutilized foods
Local	Diet	underutilized food	underutilized foods
Local	Diet	wild food species	wild food species
Local	Future	animal wild relative	animal wild relative
Local	Future	crop wild relative	crop wild relative
Local	Future	endangered cultivated plants	endangered cultivated plants
Local	Future	endangered livestock	endangered livestock species
Local	Future	endangered livestock	endangered livestock varieties
Local	Future	endangered poultry	endangered poultry species
Local	Future	endangered poultry	endangered poultry varieties
local	Future	participatory breeding	participatory breeding
Local	Future	traditional breeding	traditional breeding
Local	Production	ancestral agriculture	ancestral agriculture
Local	Production	ancestral variety	ancestral variety

Sub-theme	Theme	Concept unified	Concepts
Local	Production	artisanal fishing	artisanal fishing
Local	Production	cultivate ancestral crops	cultivate ancestral crops
Local	Production	cultivate domesticated crops	cultivate domesticated crops
Local	Production	cultivate endangered crops	cultivate endangered crops
Local	Production	cultivate heirloom crops	cultivate heirloom crops
Local	Production	cultivate heritage crops	cultivate heritage crops
Local	Production	cultivate indigenous crops	cultivate indigenous crops
Local	Production	cultivate local crops	cultivate local crops
Local	Production	cultivate native crops	cultivate native crops
Local	Production	cultivate neglected crops	cultivate neglected crops
Local	Production	cultivate orphan crops	cultivate orphan crops
Local	Production	cultivate threaten crops	cultivate threaten crops
Local	Production	cultivate traditional crops	cultivate traditional crops
Local	Production	cultivate underused crops	cultivate underused crops
Local	Production	cultivate underutilized crops	cultivate underutilized crops
Local	Production	domestic livestock	domestic livestock
Local	Production	domesticated animal diversity	domesticated animal diversity
Local	Production	domesticated breed diversity	domesticated breed diversity
Local	Production	domesticated crops diversity	domesticated crops diversity
Local	Production	domesticated plants diversity	domesticated plants diversity
Local	Production	domesticated species diversity	domesticated species diversity
Local	Production	heirloom variety	heirloom variety
Local	Production	heirloom variety	heirloom variety
Local	Production	heritage variety	heritage variety
Local	Production	indigenous breed	indigenous breed
Local	Production	indigenous crops	indigenous crops
Local	Production	indigenous fish	indigenous fish
Local	Production	indigenous poultry	indigenous poultry
Local	Production	indigenous variety	indigenous variety
Local	Production	landrace	landrace
Local	Production	landrace varieties	landrace varieties
Local	Production	landscape complexity	landscape complexity
Local	Production	local breed	local breed
Local	Production	local fish	local fish
Local	Production	local livestock	local livestock
Local	Production	local poultry	local poultry
Local	Production	local varieties	local varieties
Local	Production	native varieties	native varieties
Local	Production	neglected crops	neglected crops
Local	Production	neglected plants	neglected plants
Local	Production	neglected species	neglected species
Local	Production	orphan crops	orphan crops
Local	Production	threaten breed	threaten breed
Local	Production	traditional crop	traditional crop
Local	Production	traditional fisheries	traditional fisheries

Sub-theme	Theme	Concept unified	Concepts
Local	Production	traditional landrace	traditional landrace
Local	Production	traditional pastoralism	traditional pastoralism
Local	Production	traditional variety	traditional variety
Local	Production	underused crops	underused crops
Local	Production	underused crops	underused crops
Local	Production	underused species	underused species
Local	Production	underused species	underused species
Local	Production	underutilized crop	underutilized crop
Local	Production	underutilized crop	underutilized crop
Local	Production	underutilized plant	underutilized plant
Local	Production	underutilized plant	underutilized plant
Local	Production	underused crops	underused crops
Local	Production	underused species	underused species
Local	Production	underutilized crop	culturally valuable
Local	Production	underutilized crop	underutilized crop
Local	Production	underutilized plant	underutilized plant
Local			farming traditional approach
Local			fisheries traditional practices
Plants			crop
Plants			plants
Plants			tree
Plants			varieties
Production	Production	agriculture pastoralism integration	agriculture pastoralism integration
Production	Production	agroecological	agro-ecological
Production	Production	agroecological	agroecological
Production	Production	agropastoral system	agro pastoral
Production	Production	agropastoral system	agropastoral
Production	Production	agrosilvopastoral	agro silvopastoral
Production	Production	agrosilvopastoral	agrosilvopastoral
Production	Production	animal plant integration	animal plant integration
Production	Production	beneficial insects	beneficial insects
Production	Production	beneficial insects	insects beneficial
Production	Production	biodiversity-friendly practices	biodiversity-friendly practices
Production	Production	biological agriculture	biological agriculture
Production	Production	biological production	biological production
Production	Production	biopesticides	biopesticides
Production	Production	biopesticides	biocontrol
Production	Production	biopesticides	biological pest control
Production	Production	biopesticides	biological pest management
Production	Production	biopesticides	biopesticides
Production	Production	climate smart agriculture	climate smart
Production	Production	climate smart agriculture	climate smart agriculture
Production	Production	conservation agriculture	conservation agriculture
Production	Production	crop fish integration	crop fish integration
Production	Production	crop fish system	crop fish system

Sub-theme	Theme	Concept unified	Concepts
Production	Production	crop-livestock integration	crop-livestock integration
Production	Production	crop-livestock system	crop-livestock system
Production	Production	eco-compatible practices	eco-compatible practices
Production	Production	fallow land	fallow land
Production	Production	fisheries conservation	conservation fisheries
Production	Production	fisheries conservation	fisheries conservation
Production	Production	integrated aquaculture	integrated aquaculture
Production	Production	integrated cropping	integrated cropping
Production	Production	integrated landscape	integrated landscape
Production	Production	integrated pest management	integrated pest management
Production	Production	integrated pest management	ipm
Production	Production	integrated plant management	integrated plant management
Production	Production	integrated seascape	integrated seascape
Production	Production	low input agriculture	agriculture low inputs
Production	Production	low input agriculture	low input agriculture
Production	Production	microorganisms management	microorganisms management
Production	Production	mixed crop-livestock	mixed crop-livestock
Production	Production	mixed cropping	mixed cropping
Production	Production	mixed farming	mixed farming
Production	Production	multifunctional landscape	multifunctional landscape
Production	Production	multifunctional seascape	multifunctional seascape
Production	Production	natural enemies	natural enemies
Production	Production	natural pest enemies	natural pest enemies
Production	Production	nature-based solutions	nature-based solutions
Production	Production	nutrient-dense crops	nutrient-dense crops
Production	Production	nutrient management	management soil nutrients
Production	Production	nutrient management	soil nutrient management
Production	Production	organic agriculture	organic agriculture
Production	Production	organic aquaculture	organic aquaculture
Production	Production	organic farming	organic farming
Production	Production	organic fishing	organic fishing
Production	Production	organic production	organic production
Production	Production	organic products	organic certification
Production	Production	organic products	organic management
Production	Production	organic products	organic products
Production	Production	regenerative agriculture	regenerative agriculture
Production	Production	soil biodiversity	soil biodiversity
Production	Production	soil biota	soil biota
Production	Production	soil conservation measures	soil conservation measures
Production	Production	soil diversity	soil diversity
Production	Production	soil protection	soil protection
Production			agriculture green practices
Production			beekeeping
Production			beekeeping
Production			farming conservation practices

Sub-theme	Theme	Concept unified	Concepts
Production			farming diversity
Production			farming resilient practices
Production			farming sustainable practices
Production			pest
Production			traditional knowledge
production system and mgmt			agriculture
production system and mgmt			aquaculture
production system and mgmt			environmentally friendly practices
production system and mgmt			farming
production system and mgmt			fisheries
production system and mgmt			integrated management
production system and mgmt			sustainable management
production system and mgmt			vegetation
spatial scale			ecosystem
spatial scale			farm
spatial scale			habitat
spatial scale			land
spatial scale			landscape
spatial scale			seascape
spatial scale			soil