Commonwealth Futures Climate Research Cohort

Breaking silos for food production systems innovation and improved climate resilience

Final Report

Innovations for Food Systems Resilience

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Executive Summary

Climate change impacts present a current and growing challenge for food production systems across the globe. While considerable advances in climate resilient crops and technologies have been made, there are still considerable gaps between these research and development activities, and the uptake of innovations by farmers on the ground. Integrating climate-smart innovations is critical for resilient food production systems that effectively align with Sustainable Development Goals, making it vital to better understand how to bridge those gaps and adopt a more integrated and holistic approach to research, innovation, and extension.

The primary objective of this project was to stimulate discussion around the technologies and innovations that could create transformative change in food production systems, the barriers that hamper their adoption, and the opportunities and pathways moving forward. To achieve this, we developed four country case studies about food production systems innovations, using existing research, in-person stakeholder meetings, and virtual engagement. This was followed by a synthetic exercise to summarise and present lessons learned across the case studies, and included mapping linkages with Sustainable Development Goals and the key successes and barriers encountered in the case studies.

Across the case studies, inadequate funding and resources, and the complexity of innovations presented the greatest barriers to adoption and scaling up. The case studies also highlighted the importance of knowledge brokers, embracing inclusive approaches, supporting equitable access to and sharing of information, and tailoring solutions to suit the context. Ultimately, innovative technologies and solutions to climate resilient food production, and the integration of traditional and new practices, can enable the food production systems transformations we need, but only with attention paid to thoughtful development, meaningful communication, and context-specific implementation.

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1. INTRODUCTION

1.1. Background / Context

Climate change impacts from increasing temperatures, more variable rainfall, and elevated frequency of extreme events, present a growing challenge for food producers and agriculture and fishery systems (Bell et al., 2016; Müller et al., 2011). Food systems are also regarded as a major driver of climate change, particularly through inefficient use of fertilizers, livestock produced emissions, and as a cause of habitat destruction and land use change (Springmann et al., 2018). In order to tackle these challenges head-on, we need climate-smart management practices, innovations, and technologies (Sayer and Cassman, 2013; Westermann et al., 2018).

At the same time, there is an existing gap between the development, communication, and adoption of critical climate-smart innovations and technologies in food production systems (Knickel et al., 2009). The research community has made considerable advances in the breeding of climate-resilient crop varieties, the development of water-efficient technologies, the improvement of soil fertility and nutrient application (Sayer and Cassman, 2013), and even the integration of traditional knowledge and practices into contemporary farm management (Makate, 2019; Tall et al., 2014). Several factors are influential in the adoption of new technologies in the farming sector, including methods of information transfer, characteristics of the technology, farm traits, as well as socio-demographic, economic, and institutional factors (Greenland et al., 2019; Kumar et al., 2018; Senyolo et al., 2018). While in many instances appropriate technologies and interventions are available, there is still a major gap between research and development activities, and the uptake of innovations on the ground (Stevenson et al., 2019).

1.2. Need for Research-to-Action

One of the important things to acknowledge when dealing with food systems, is how context dependent both the problems and solutions are. In some contexts, it is necessary to recognise what research and innovations are still needed, while in others, the gap is in understanding how to connect research and innovation to grassroots users, and encourage uptake where warranted. Ultimately, to address the challenge of food security under a changing climate, we need to break silos between the development of appropriate interventions, communication and dissemination of these actions, and the adoption of technologies and interventions that are appropriate.

With population increasing and urbanizing, growing pressure on natural resources, and looming changes to the climate, farmers and fishers increasingly face conditions outside of their lived experiences, and beyond their capacities to cope. Innovative technologies and solutions, and the integration of traditional and new practices, can enable the food systems transformations we need, but only with attention paid to thoughtful development, meaningful communication, and successful implementation. Thus, a more integrated and holistic approach to research and innovation is critical for resilient food production systems that effectively align with Sustainable Development Goals.

1.3. Objective(s) of the R2A Project

Primary objective: Stimulate discussion around underutilised technologies and innovations that could lead to transformative change in food production systems, the challenges and barriers that are hampering their adoption, and opportunities/ pathways moving forward.

Secondary objective: Synthesise lessons on the progressive changes required on research and innovation, policies, and strategic approaches as they apply to climate change mitigation and adaptation, and with an eye specifically to the COP26 processes.

2. METHOD / APPROACH

To achieve the above objectives, the project was separated into two components: (1) case study development and dialogue, and (2) a synthetic exercise to summarise and present lessons learned across the case studies.

2.1. Case study briefs

This first step involved gathering evidence from localised case studies, which highlight innovations and technologies to be used in food production systems in the face of climate and pandemic threats, and identify the value and the challenges. Case studies were based on the experiences and research areas of the team members.

For each of these case studies, we developed a written brief (in consultation with others as needed), with main messages and questions to stimulate stakeholder discussions. Each case study brief followed a standard format, outlining background information on the context, food production system component(s) involved, climate change challenges, and innovation, concluding by posing a set of discussion questions.

Where external consultation was required, a series of in-person and virtual engagement activities was carried out. For the case study development in Nigeria and Sri Lanka, there were phone calls and in-person meetings with key informants in the different stakeholder categories to support accurate information gathering on the subjects of the case studies. For the Nigerian case study, representatives from academia, farmer cluster groups, extension agencies, and private sectors groups, as well as policy-making bodies, government agencies, UNFCCC negotiators, NGOs and climate advocacy groups were hosted at engagement meetings on the subject of the case study, and for mobilisation of future online activities. Many of these stakeholders may not ordinarily visit an online platform due to a number of factors. The Sri Lankan case study was based on the contributions by farmers, agripreneurs, the state sector (Ministry of Agriculture, Agrarian service department, and extension services), Agri Food industry (CIC, CBL), research and academia, administration and policy making bodies and the International organizations (UNDP). The sessions were conducted in-person or via online platforms and social media.

2.2. Synthesis exercise

In order to synthesise lessons across case studies, we took a two-pronged approach. First, the case studies were mapped against the different sustainable development goals (SDGs), based on their subject matter, objectives, and achievements. Between the case studies, this allowed for comparisons of their contributions to established targets, using an existing framework. It helped to establish the broad thematic commonalities and differences between case studies.

Second, through group discussion, we drew out key successes and barriers that arose in the case studies. These lessons focused more on the 'how' of achieving the SDGs and climate resilient food production systems. We identified specific examples in case studies to illustrate the themes. Lessons from the synthesis are included in this report, section 4.

3. FINDINGS / UNDERSTANDING THE LANDSCAPE

3.1. Case Studies

3.1.1. Improving efficiency in adaptation to climate impacts in fish farming in Nigeria

Nigeria is the second highest aquaculture fish producing country in Africa, and yet it is among the top ten most exposed countries to the effects of climate change and extreme weather events (Okon et al. 2021). In Nigeria, rising sea level and ocean surges threaten marine and coastal aquaculture, flooding challenges inland aquaculture, and smallholder fish farmers are among the most devastated

At the same time, in Africa, smallholder fish production units are often plagued by limited resources to cope with climate change related challenges. They face substantial gaps in access to climate-Smart innovations and technologies (CSI&T) to support adaptation. CSI&T for adapting smallholder food systems could include solutions in fish breeding, hatchery and pond consolidating techniques, disease control and sustainable feed sources, satellite and mapping technology, ecological modelling, mobile knowledge transfer and mobile systems, and enabling local services. However, these innovations appear to be locked up in the silos of knowledge at a national level, while smallholder fish farmers' resilience remains below expectation in Nigeria.

With all of these options to adapt as climate change threatens food production units, what can be done to help smallholder fish farmers access and adopt innovations and technologies? Stakeholder engagement has shown that adaptation is constrained by barriers at both local and national levels. One way to improve adoption is to promote private or voluntary extension agents (VEA), who could bridge the existing knowledge gap for improved adoption of CSI&T in the smallholders farming communities.

3.1.2. Seasonal farm advisories in Papua New Guinea

Climate change is expected to negatively impact island nations in the Pacific, which are particularly vulnerable to shifts in rainfall, sea level rise, and increased storm intensity. The people of Papua New Guinea, the largest of the South Pacific islands, rely mostly on small-scale agriculture and traditional practices for their livelihoods. In order to ensure their farming can respond to imminent climate threats, and build resilience over time, smallholders will need to be able to adapt their practices and food systems structures. This will require new knowledge, understanding, and approaches, but producing and sharing climate-relevant information so that it is accessible, useful, and equitable, remains a challenge.

Seasonal climate forecasts and farmer feedback can be used to design farm advisories, which translate short, medium, and longer-term climate forecasts, alongside agricultural production and market information, into accessible and understandable guidance for farmers to adapt their crop varieties and management practices. These advisories can identify specific crops or varieties that would fare best under above- or below-average rainfall, and suggest modifications to irrigation and fertiliser applications. In PNG, we know traditional knowledge is important, tailoring advisories to suit men and women can overcome some gender inequities, and information products must reflect geographic differences. However, questions still remain about process - how to bridge traditional knowledge and climate forecasts, how to co-design information services with communities, and how to adapt advisories in response to shifting conditions and farmer needs.

3.1.3. Incorporation of technology to enhance aquaculture in a closed system in Singapore

A changing climate will impact coastal nations more than most. Not only by rising sea levels and increasing storm surges, but also by impacting fishing activities. More storms, disease, and lower pH levels in our waters will make farming fish in the natural environment less productive. In low income regions in Asia, fisheries are a major source of income, as well as an important source of protein for the overall Association of Southeast Asian Nations (ASEAN) community. To mitigate the coming climate related issues, many fish farmers are opting to farm fish on the land. While this solves many of the climate related issues, it has some serious technological issues that low income farmers are not well-placed to adapt to when adopting these new technologies.

With the migration of fish farming to the land, we see an increase in closed aquaria being employed. In these environmental systems, there is no fresh water continually being drawn to dilute and flush through the pollutants that accumulate in the aquaria. Furthermore, the lack of fresh water creates a perfect breeding ground for diseases. We see infections within communities of fish spread as the physical space between the fish. Therefore, several commercial ventures are tackling land/closed based aquaculture systems to make the technology more efficacious. This can be through the improved filtration of waste products already in the closed systems, proactive measures to monitor the microbiology of the systems, or even digital video surveillance to immediately spot any signs of disease or stress.

The technologies are revolutionising aquaculture in the ASEAN region. However, where does this leave the low income fish farmer? They may not have the education or financing to access, let alone install and maintain such systems.

3.1.4. Neglected and underutilized crops (NUCs) to improve climate resilience in Sri Lanka

In traditional systems, farmers effectively used crop biodiversity to develop resilience and adaptive capacity to extreme weather. This case study examines how we can invest and what needs to be investigated to enhance commercial and nutritional potential of NUCs in Sri Lanka.

NUCs offer nutrition dense alternatives, and smart crops for resilient agriculture. Less water and input demanding NUCs, can be used to increase cropping intensity, and resource use efficiency while reducing carbon footprints in farming systems. NUCs can promote local technology and local seeds to develop local food chains and thereby increase income for rural communities. Therefore in the long run NUCs can ensure food security but also food sovereignty. Developing high-value agriculture by strategic integration of NUCs can increase income and create significant opportunities for women, youth and rural communities.

Increased public awareness, access to information and efficient extension services; enhanced climate preparedness by farmers; technology integration in farming, and value chain development are five important pathways forward for increasing NUCs cultivation and production. NUC farmers often cultivate in marginal farms in climate vulnerable conditions. Risk-averse farmers underinvest on cultivation. Access to accurate weather information is therefore imperative for farmers to make informed decisions on the cultivation and investments. Flexible credit programs by the state and private sector helps farmers in financial stresses. Crop insurance systems are vital to assist farmers to cope with losses caused by unpredictable extreme weather. Technology integration in farming and value chain operations enable NUC integration in high-value production, processing and value addition to cater to the emerging nutrition and healthy food demand. Furthermore, flexible systems to obtain local and international quality standards create new markets and enable local products and agripreneurs to enter the international markets. Public education is vital to promote nutrient–rich foods and NUCs usage. Joint initiatives by private and public sector stakeholders and actors in the value chain are necessary to create collaborative platforms, national and international networking and innovation hubs or centres of excellence to expedite delivery of appropriate, new technologies for NUCs mainstreaming. Yet inclusive planning and implementing cross-sector programs are nonexistent or weak in the current policy framework structure. Linking the different actors, including farmers, state and private sectors through the above five pathways for NUCs mainstreaming is an urgent need to leverage positive transformations, healthy and affordable food access and climate resilience in local food systems.

3.2. Interview Results / Stakeholder Consultation Outcomes

In addition to online and physical stakeholder engagement, in-person interviews and field visits to stakeholder farmers were carried out in Nigeria and Sri Lanka. Other than consumption of subsistence production, farmers select crop portfolios and agronomic practices for a variety of locally relevant reasons including cultural relevance, medicinal values, agronomic, industrial and commercial purposes. The discussions identified practical constraints that slow technology adoption in local fish and crop farming. Discussions and interviews with research and academia, industry and marketers, the state sector, and policy makers revealed the existing and novel opportunities for expansion of cultivation and profits in aquaculture and crop production. The discussions further identified bottlenecks farmers and industry face when adopting sustainable practices under the current policy and market structures. The contributions by the international players such as UNDP provided insights into global developments and enabled identifying new directions for developing local aquaculture, agriculture, and agri industry towards more sustainable production systems and supply chains

4. SYNTHESIS OF THE FINDINGS

4.1. Climate resilient food production systems and the Sustainable Development Goals

In 2015, at a historic United Nations Sustainable Development summit, world leaders adopted the 2030 Agenda for Sustainable Development and pledged to achieve a set of 17 goals by 2030 with the general aim to end extreme poverty, reduce inequality and protect the planet. Food production systems are inextricably linked to the SDGs, and provide both opportunities and challenges to advance them.

The scale and sheer ambition of the SDGs require innovation to achieve them. This is true in the case of agricultural innovations, where their widespread adoption would be a key enabler for attaining many of the related SDGs. It is also important that the innovations in question are environmentally sound, socially inclusive, and economically viable in the context of the implementing country. The pathways to achieving SDGs through innovation can be diverse amongst different regions, and therefore require customized solutions to accelerate their achievement. In looking at country specific scenarios, we develop a more complete picture of how specific SDGs are influenced by the present gap between the technological advances for climate adapted food production systems and their actual usage by farmers and fishers.

Based on the case studies, climate resilient farming and aquaculture systems are strongly connected to more than half of the SDGs and thus have a role to play in accelerating progress towards them. Furthermore, many of these SDGs themselves have synergies with one another leading to often surprising alignments that are not mentioned here and thereby contributing to additional complexities in number and depth. For example, food security and peace are often mutually reinforcing and thus through SDG 2, innovations in food systems can have a positive effect on promoting 'just, peaceful and inclusive societies' (SDG 14).

Figure 1 below maps climate resilient food production systems against the SDGS in the context of the four case studies.

The specific SDGs that are crucial to bridging the present gap between the technological advances and their actual usage by farmers and fishers included several that were not mapped under figure 1. For example, it includes quality education (SDG 4) and affordable and clean energy (SDG 7), where the former contributes to greater human capacity development and acceptance of new technology, while the latter can be a necessity for innovative advances in climate adaptation. Another important SDG in this regard is gender equality (SDG 5) as many females in developing nations are a marginalized group with regard to education, and often do not enjoy equal property and economic rights. SDG 8 on decent work and economic growth as well SDG 9 on industry innovation and infrastructure would be necessary for greater acceptance and availability of innovative technological solutions in the agriculture sector.

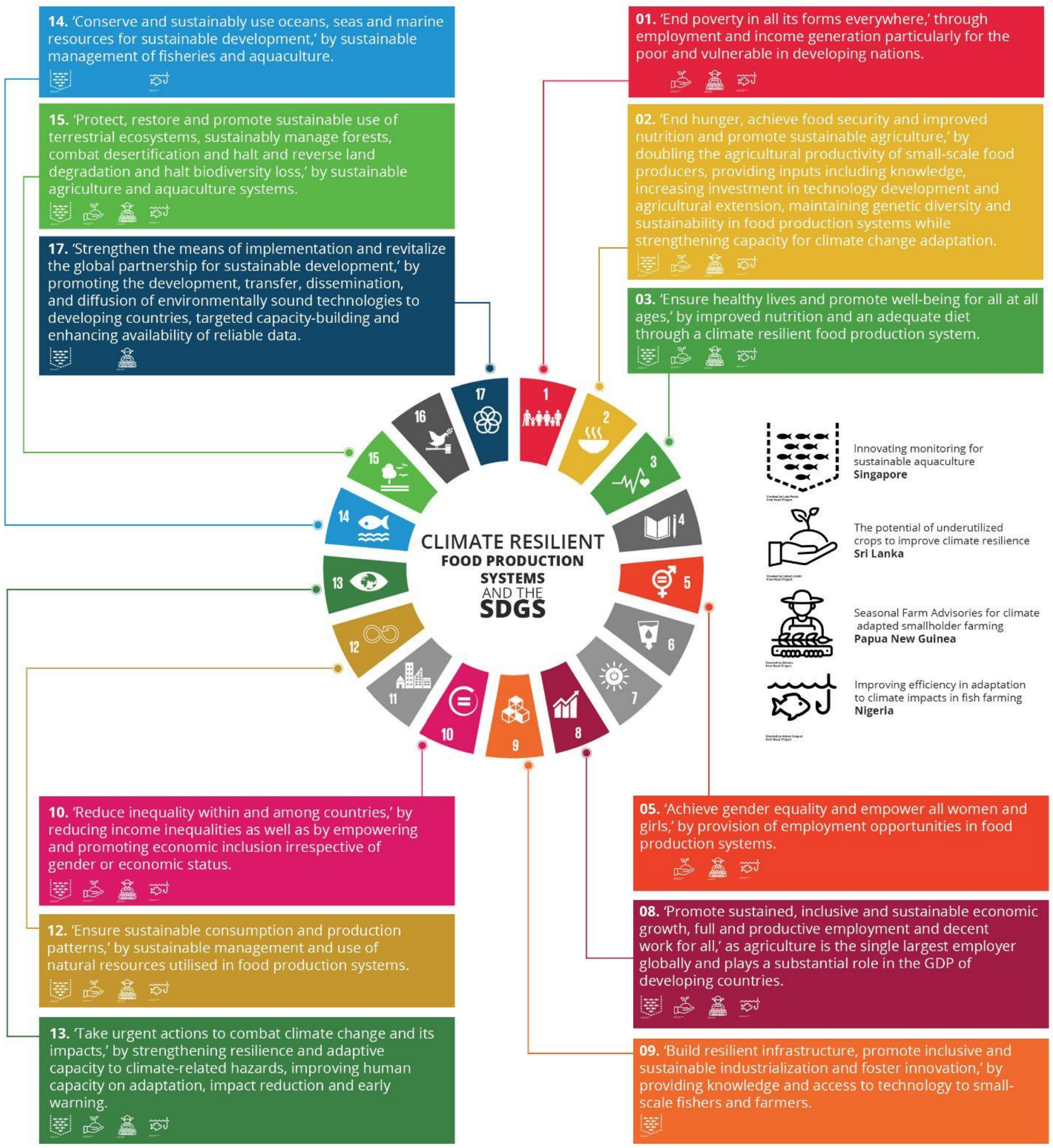

Figure 1. An overview of the SDGs that show strong linkages with climate resilient food production systems in the context of the four case studies.

The disparity between the perspective of SDGs on food production systems in the Global North and Global South was seen even within the small cohort of case studies used. According to Campbell et al. (2018) the Global South tends to focus on food production, food security and adaptation, while the Global North is more focused on mitigation strategies and the environmental impacts of food systems. This further hints that the pathways to achieving SDGs is also diverse amongst different regions and it therefore requires customized solutions. Though there is an interest in climate resilient agriculture, many developing nations have financial and capacity related challenges in implementing adaptation strategies. This brings to the forefront the need to achieve SDG 17, where global partnerships are strengthened in order to further sustainable development.

4.2. Other Lessons for Achieving Goals and the Paths Forward

While it is of use to consider how innovations in food production systems can help achieve the Sustainable Development Goals, there are a number of other lessons these case studies highlight in terms of the development, dissemination, and adoption of these innovations in practice. Common barriers and factors for success emerged from the case studies.

4.2.1. Common barriers

To improve farmers' and fishers' access and adoption of innovations and technologies for climate change adaptation, it is essential to understand what is standing in their way. Our case studies highlight two challenges that plague climate-smart innovations and technologies. For one, new practices or techniques may be complex and difficult to understand without proper technical knowledge or training. Second, inadequate funding and resourcing means that extension and training opportunities are inadequate to understanding the tools available, and how to use them.

The challenges associated with overly complex technologies or practices were evident in the case studies. For example, the Singapore case study illustrated how moving aquaculture onto land involves technology that many fishing operations are unfamiliar with, and may require specific technological knowledge to operate. On the information side, in Papua New Guinea, seasonal climate forecasts can provide critical information for farmers to use in planning their land preparation, planting, and harvest. However, the uncertain and probabilistic nature of forecasts make them difficult to interpret without some explanation or background knowledge. In Sri Lanka, while underutilised crop varieties themselves may be 'low-tech', limited technological knowhow and use of IT in farming activities can be a barrier to achieving the yields that would make these crops attractive.

Strained financial resources are frequently cited as a challenge in getting innovations to users, from the actual cost of the technology to the resources needed to disseminate it. Again, the case in Singapore illustrates how valuable technology may remain in the hands of wealthier nations (and producers); land-based aquaculture involves high costs both for installation and upkeep. Conversely, in the case of Neglected and Underutilised Crops, more resources and incentives are needed to improve seeds, and to encourage the adoption by risk-averse farmers. In Nigeria, more funding is needed to train and support extension agents who can disseminate information about climate-smart technologies to the grassroot users. Similarly, in PNG, seasonal climate forecasts are produced by technical experts within the weather service, but without additional staffing and funds for media, it is nearly impossible for most farmers to actually access and use this information.

4.2.2. Solutions for success

The case studies did not only focus on the negatives - the factors hindering innovation - but also provided glimpses into pathways to success. In particular, the cases highlighted the importance of trained and supportive knowledge brokers to connect innovations to users, the value of inclusive approaches and equitable knowledge sharing, and context-specificity in the development and dissemination of technologies and innovations.

Knowledge brokers appeared to be pivotal in some of the case studies. For instance, in Nigeria, the use of Voluntary Extension Agents for smallholder farmers can boost information dissemination across stakeholders that are often underserved by the government. In PNG, government extension services provide advice on crop varieties, land preparation and planting time, as well as market-based activities. However, they also have established relationships with some communities, while others are underserved, highlighting the need to expand the services or find a viable alternative for information sharing.

Adopting inclusive approaches to developing innovations is also critical for effective adoption. In Sri Lanka, small-scale and resource-poor farmers operate in complex and diverse environments where there is a high degree of heterogeneity in their farming systems. Top-down and blanket approaches to innovations often fail due to variable interactions with technologies. Participatory approaches enable identifying relevant knowledge, collaborative learning and developing knowledge-based -practices. Such approaches ensure efficient management of natural resources in agriculture, empower local farming communities to improve their agricultural practices and methods, and thereby promote equitable distribution of the benefits of the technology and increased agricultural production. For example, participation of farmers and the rural sector, along with market actors, researchers, and policy makers is very important in identifying priority Neglected and Underutilised Crops. Inclusive approaches may be particularly important for technologies such as those for aquaculture in Singapore, where initial development is driven by powerful or well-endowed industry actors.

One of the factors that influences the success or failure of an innovation is in the process of how knowledge is developed and shared, and ensuring that is equitable. In PNG, illiteracy and lack of ownership of communication devices (e.g. radio, mobile phones) makes it difficult for women to access climate information services. Using oral or visual modes of communication through social groups is an effective means of sharing adaptive practices or early weather warnings. In the case of Neglected and Underutilised Crops, it's critical to include indigenous knowledge holders and basing the choice of crops on local understanding. Indigenous Knowledge systems are associated with holistic understandings of local ecosystems, and by linking these knowledge systems enable co-production of knowledge for enhancing food production, extreme weather and natural disaster preparedness, and biodiversity management to create sustainable development solutions.

Finally, context matters when developing adaptation strategies, and is a crucial consideration to ensure innovations and technologies are suitable and accessible for local users. Our four case studies illustrate the challenges and opportunities for climate-smart food production in diverse contexts. And while there may be transferable lessons, each has its own particular needs and constraints. Cases ranged from small-holder subsistence horticulturalists to larger-scale aquaculture producers, with a variety of languages, cultures, and socio-economic and political constraints. Using tailored solutions, rather than a one-size-fits-all approach, is fundamental to ensure climate-smart innovations make it to those in need.

5. STAKEHOLDER ENGAGEMENT

In Sri Lanka, A series of activities including field visits, online sessions and social media campaigns were launched to build awareness on NUC conservation, utilization, consumption and nutrition food targeting the general public and youth parallel with the case study. Opportunities were created for youth engagement in the process.

Seeds of four NUC cereals including finger millet, Codo mille, pearl millet, and foxtail millet were distributed among twenty progressive NUC farmers who were identified as nodal farmers from nine administrative districts. A pocket guide book describing agronomic practices and NUC cultivation, processing and value addition was also provided. The program was initiated as a pilot project and implemented in collaboration with the Field Crop Research and Development Institute (FCRDI), Department of Agriculture. In the future, NUC seeds will be distributed and popularized among the farming communities through the nodal farmers. FCRDI and the research group led by the author will monitor progress of the program.

A typical grassroots aquaculture food system in Nigeria was also engaged to explore the dimensions of the existing climate smart innovation and technology silos in the aquaculture food system in a three-staged stakeholder engagement activity. Stakeholders were physically engaged at the grassroots, virtually engaged at the high power national level and physically engaged at a physical feedback meeting at the grassroot. The engagements focused on the critical question “why are the grassroots’ fish farmers frustrated by climate events when there exists scientific outputs and government policies on climate-smart approaches in fish farming? Also, what can be done to improve adaptation to this challenge? The output of the first grassroots stakeholders’ meeting was presented at the national level for discussion, while the output of the national meeting was presented and harmonized at the feedback meeting. The stakeholder’s engagement activities enabled a collation of participant’s views and trending adaptation strategies which can be published as an extension manual in the future. The activities also produced a cross-section of grassroot and national players for future engagement. Future intervention could be facilitated en-route the obtained contact and relationship with the engaged stakeholders. The four case studies were presented to a wider audience through selected platforms to create more opportunities for discussion and engagement.

6. RECOMMENDATIONS AND CONCLUSION

Based on the case studies and synthesis presented in this report, there are a number of recommendations to put forward for achieving both food production systems innovation and improved climate resilience. These include, but are not limited to:

1. Technologies exist and continue to be developed. More financial resources and training are needed from governments, donors, and industry to enable access to and adoption of appropriate innovations.
2. Much of the innovation that receives funding and attention is developed at a high-level and can be complex or technically demanding. Innovation also happens at small-scales and grassroot levels, but doesn't receive the same support. Co-production and other inclusive approaches should be employed in climate-smart innovation development.
3. Access, particularly for poor or marginalised groups, is a critical barrier to wide-spread adoption and building of resilient food production systems at all levels. More attention needs to be paid both by those developing and disseminating innovations to ensure these groups are not overlooked.
4. Context matters. Not all shiny technologies will be accepted in every situation. Cultural, geographic, and gender-based specificity can affect how appropriate innovations are, and whether they effectively support resilient food production systems. Those developing new technologies should consult with their end users from the start, about their needs, existing constraints, and concerns for climate adaptation.

Innovative technologies and solutions, and the integration of traditional and new practices, can enable the food systems transformations we need, but only with attention paid to thoughtful development, meaningful communication, and context-specific implementation. These case studies demonstrated a number of constraints, as well as opportunities, for innovation in the face of climate change. With all the myriad tools available within food production systems, it ultimately comes down to finding the right fit, and doing so in an inclusive, consultative, and context-specific manner. This is not the end of the journey, though. Each case study raises its own set of questions, which remain to be answered moving forward.

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8. ANNEXES

Case Studies

1. Improving efficiency in adaptation to climate impacts in fish farming in Nigeria

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Case Study: Improving efficiency in adaptation to climate impacts in fish farming in Nigeria

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How can we bridge the gap between scientific and technological advances for climate adaptation in food production systems, and the implementation and adoption by farmers on the ground?

This case story is one of the contributions to the Research to Action (R2A) Project on "Breaking silos for food production systems innovation and improved climate resilience". It is a part of the cross-case study under the food system subgroup of the Association of Commonwealth Universities (ACU) Climate Research Cohort. It contributes to the broad question:

Summary

- Food systems in many developing countries rely on smallholder production units, which are often plagued by limited resources to cope with the challenges related to climate change.

- Limited resources is a critical challenge in Africa's aquaculture, where production is mostly driven by clusters of small holder fish farming communities who depend on rain-fed cultivation systems, and are highly vulnerable to risks related to climate change.

- Sustainable food production requires equipping smallholder farming clusters with adequate knowledge on climate change adaptation, but there a gap in access to relevant knowledge on climate-smart innovations and technologies (CSI&T) among smallholder fish farmers in Africa.

- This case study employed bottom-top stakeholders' engagement to highlight the climate change knowledge and experiences of the smallholder fish farmers' clusters, comparing their adopted adaptation strategies to the existing CSI&T at the national level

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Background

Africa's food system faces many challenges due to climate change, and could be adapting inefficiently with the aid of existing climate-smart aquaculture innovations and technologies. Climate-smart aquaculture innovations and technology (CSI&T) could include technology solutions such as fish breeding and hatchery technology, disease control systems, new sustainable feed sources and nutrition-sensitive, low-cost and low environmental impact production systems; and leveraging on the latest information communications technologies (ICTs) such as satellite and mapping technology, ecological modelling, mobile systems and open data (Worldfish, 2017). There are innovations that target consolidation of pond systems against climate-induced flooding effects, enabling local services and use of mobile knowledge transfer techniques to increase access and reach of technical information, finance and market knowledge. However, in Nigeria, this knowledge of climate smart aquaculture practices appears to be locked up in the silos of knowledge at National levels, and smallholder fish farmers' resilience remains below expectation. This begs the question of whether climate-smart aquaculture innovations and technology really in reality strengthen the resilience of vulnerable fish farmers. How much of the knowledge and technology is actually accessible to and used by them? And ultimately, what can be done to improve the situation, as climate change continues to threaten these food production units?

Current Context

Country background

Nigeria is a country in West Africa. It shares land borders with the Republic of Benin in the west, Chad and Cameroon in the east, and Niger in the north. Its coast lies on the Gulf of Guinea in the south and it borders Lake Chad to the northeast. Nigeria has a tropical climate with variable rainy and dry seasons. It is hot and wet most of the year in the southern part, dry in the North and farther inland. Rainy season lasts from March to November in the south, mid-May to September in the far north. Worldometer elaboration of the latest United Nations data revealed that Nigeria has an estimated 206,139,589 population as at 2020, which was 2.64% equivalent of the total world population; ranking number 7 in the list of countries (and dependencies) by population. Nigeria's population density is 226 per Km^2 with a total land area of 910,770 Km2. Median age in Nigeria is 18.1 year and about 52.0 % of the population is urban.

Aquaculture and fish farming systems

Aquaculture is a fast developing sector that plays a critical role in supplies of animal source food, employment, and poverty reduction. Nigerian aquaculture production is the second-largest in Africa, and it is largely dominated by catfish culture (Ozigbo et al. 2014; FAO 2018). Nigeria produced 370,000 metric tons of fish from aquaculture systems in 2016 valued at over USD 1.3 billion (BusinessDay 2017). Nigeria's aquaculture production accounts for about 34% of the total national fisheries production, employs about 475,000 people and contributes 4.5% to GDP (WorldFish 2017). Aquaculture creates jobs and livelihoods for many young school leavers and women, especially at the grassroot. However, Nigeria with a population of over 200 million (Pison 2019), has the highest fish demand in Africa (Cai et al. 2017). Nigerian aquaculture is mainly driven by clusters of smallholder fish farming units, which face myriad challenges from climate change, and have become more vulnerable under the current pandemic. The challenges only seem to increase despite national and institutional efforts aimed at fortifying the food system for sustainable production.

Climate change impacts

There is evidence that Nigeria is already experiencing environmental challenges attributed to climate change and its impacts; and there is the need for knowledge-based strategies to help plan adequate mitigation and adaptation measures for the country (Okon et al., 2021). Nigeria is one of the top ten most exposed countries to the effects of climate change, with about 6% of its land area estimated to be exposed to extreme weather events (World Bank, 2019). Aquaculture can be adaptive to the impacts of climate change, but it is not completely insulated against it (Oyebola and Olatunde, 2019). Climate change was projected to continue to increase rainfall variability and subsequent flooding in some humid areas of the forest regions and savanna areas in southern Nigeria (Olapido, 2010). This scenario is already having serious negative impacts, especially on smallholder fish farmers in southern Nigeria. In Nigeria, aquaculture can be practiced in coastal, marine and inland areas. However, it is projected that floods near the coast will be exacerbated by rising sea level in southern Nigeria (Akande et al., 2017). The rising sea level and ocean surge has submerged villages in Lagos and some places in the Niger Delta area in Southern Nigeria (Anabaraonye et al., 2019). This threatens marine and coastal aquaculture in Nigeria. The alternative is to utilise inland aquaculture, which is the most popular in the southwest, the hub of aquaculture in Nigeria. However, flooding is threatening sustainable aquaculture in this zone and fish farmers need some innovation in order to adapt. Although some technical innovations for adaptation have been identified in this regard (Oyebola et al., 2018), it is interesting that smallholder fish farmers still suffer much damages from climate change mediated flood disasters in Nigeria.

Addressing the Challenge

Spotlight on a Typical Smallholder Aquaculture Food System in Nigeria

The Ijebu Development Initiative on Poverty Reduction (IDIPR), Ijebu-Ode, Ogun State, southwestern Nigeria is a grassroots effort targeting food production for improved livelihood, food security, and poverty reduction in Nigeria. The IDIPR farming initiative has supported Nigeria's food system at local and national levels, contributing significantly to poverty alleviation as well as improving employment for women and youth. The 1,327 farmers involved in the initiative have access to 156 hectares of land at subsidized rate, production inputs and financial support (to be repaid at harvest) through the cooperative arm of the NGO. The initiative also transports fresh and processed fish for sale, and smoked fish for Nigeria's National school feeding program.

To ensure sustainable production, the IDIPR partners with local, national and international donor organizations for periodic farmer training to keep them abreast of production challenges. It is not clear whether the support by the IDIPR is in the direction of the diffusion of CSI&T. Moreover, the farmers have over the time complained of production losses due to climate change related hazards, and are getting discouraged to continue farming. Furthermore, the pandemic and incessant floods now ravage the farms.

To understand the issues underlying fish farmers' use of climate-smart innovations and technologies, and identify actions needed for a sustainable food system, researchers held discussions at the grassroots level with IDIPR fish farming stakeholders and with high-power government officials at the national level, followed by a grassroots feedback session. These discussions considered climate change experiences, tools for adaptation, and the constraints farmers face in using the available CSI&T. The critical question was "why are grassroots fish farmers frustrated by climate change, when the literature reveals a viable CSI&T from scientific outputs and government policies that could be applied for adaptation?" Answering this question could provide relevant information to project the way forward for the food system.

Adaptation is constrained by local and national barriers

The grassroots engagement revealed terrible experiences with the impacts of climate change, where fish farmers could use few climate-smart tools, and adaptation efficiency was constrained by local and national issues.

*The aquaculture food production system actors experienced huge losses of fish in production and poor quality processed fish due to climate change***.** Farmers and other actors along the value chain of the aquaculture food system at the grassroots admitted climate change negatively affected fish production. For instance flash floods, temperature variability, unpredictable rainfall, and high water tables affected production, while fluctuating temperatures impacted feed producers, fish processors, and marketing. Few innovations/technologies were utilized to cope: fish producers use concrete ponds in upland areas to protect against flooding; processors often close production or use poor quality processing materials which compromises product quality.

There were communication gaps between researchers, extension agents, and the farming community. Some known CSI&T were too complicated or costly for the farmers to adopt. Meanwhile, government officers who should assist were challenged by limited funding for farm visits and demonstrations. Limited funding also hindered government extension agents' ability to interact with researchers on latest adaptation information. Government extension agents were not visiting farmers as regularly as expected. These seemingly frustrated farmers atimes face the extension agents with stern hostility when they eventually have the opportunity to visit farms.

The stakeholders were ignorant of most of the Federal government policies on climate change adaptation and the pandemic. This was due to poor internet access and difficulty reading bulky government policy documents. To improve resilience, they called for improved, timely, adequate and efficient communication on CSI&T, particularly with grassroots stakeholders, and knowledge sharing through established platforms for food systems. Such action should be the collective role of extension agents, researchers, and policy makers.

Silos of Climate Smart Innovation and Technology at the National Level

The national level stakeholder's analysis revealed that "silos" (knowledge kept away from users) of CSI&T exist at the national level. The participants demonstrated that *CSI&T and policies were created by the government, to be explored by the farmers. However, these resources seem locked up not reaching the grassroots. It was highlighted that* there exists CSI&T on climate alert systems, climatesmart fish holding facilities, and fish feed to cope with climate-mediated diseases. There are climate extreme tolerant fish seed and fish feed ingredients. The Federal climate and Federal fisheries policy arms have enacted a number of climate adaptation policies, but most of these do not reach the end-users due to low capacity or funds. Government faces myriads of other developmental challenges, which are perceived as more grievous than the climate change in food system issues.

The private sector plays an important role in supporting CSI&T, such as placing weather forecast systems on farms. Private and non-governmental extension agents are considered potential critical alternatives for the demonstration and dissemination of CSI&T, but it is not entirely clear whether this would work in developing countries like Nigeria? For instance, Rainforest Alliance provides extension services in countries such as Ghana, for their certification programme and also climate adaptation. However, the possibility of this in Nigeria would need to be investigated. It was suggested that farmers should learn to interact with organised private sectors to copy CSI&T. Scientists should be funded to come up with new ideas to make the CSI&T more usable for farmers.. Farmer lobby groups are needed to manage the challenges of the government's lack of political will. It will be necessary to decide who is responsible for the costs of demonstration and dissemination of climatesmart innovations in developing countries like Nigeria.

Pathways forward for CSI&T use

The grassroots feedback meeting was able to produce a harmonized position for sustainable improved efficiency in utilization of the CSI&T at the grassroots aquaculture food system level. In this regard, the food system players (mostly fish farmers, farm financier-IDIPR, extension agents, representatives of local authority, and local legislators) at a grassroots feedback meeting concluded that the major constraints to accessing and using CSI&T for their fish farming included: (a) lack of awareness, manpower, adequate funding, and private extension agents; (b) ignorance and inadequate extension funding by grassroots stakeholders; and (c) low political will of the government. Local stakeholders saw a few pathways forward: (a) the creation of lobby groups to negotiate more efficiently with government at all levels, making them see reasons for improved actions (b) greater support for both public and private extension agents; (c) increased research funding for location-specific adaptation innovations; and (d) promotion of farmers clustering. Ultimately, the government must be ready to provide support for farmers, researchers, and extension services. On the way forward, farmers would need to start strategizing on how to encourage private extension practice. To be more efficient, the grassroots extension agents need to blend more appropriately with the researchers and farmers. Meanwhile, the government would need to provide a policy environment to encourage the private extension agents to play their role.

Discussion Questions

a) How best could the grassroots extension agents blend more appropriately with the researchers and farmers for improved demonstration and dissemination of climate-smart innovations and technologies in developing countries?
b) In your experience, what operational (financial, administrative/ legal/ policy) frameworks have facilitated sustainable food systems knowledge transfer in developing countries?
c) What other actions would you suggest for breaking the silos of climate change adaptation knowledge in food systems in developing countries?

These questions require further discussion. What information is still needed, that this research has not uncovered. What are your views?

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Case Study: Seasonal Farm Advisories in Papua New Guinea

Contents

How can we bridge the gap between scientific and technological advances for climate adaptation in food production systems, and the implementation and adoption by farmers on the ground?

Here we offer a case study of translating scientific climate forecasting into accessible and useful climate information services in food production systems. This provides a jumping off point to stimulate discussion on the challenges and opportunities for bridging such gaps in order to achieve transformative change and resilience in food production systems in the face of climate change. This case study was produced as part of an Australian Centre on International Agricultural Research (ACIAR) project, and contributes to a cross-case study comparison carried out in partnership with the Association of Commonwealth Universities (ACU) Climate Research Cohort.

Summary

- Climate change is expected to negatively impact island nations in the Pacific, which are particularly vulnerable to shifts in rainfall, sea level rise, and increased storm intensity.
- The people of Papua New Guinea, the largest of the South Pacific islands, rely mostly on small-scale agriculture and traditional practices for their livelihoods.
- In order to ensure their farming can respond to imminent climate threats, and build resilience over time, smallholders will need to be able to adapt their practices and food systems structures. This will require new knowledge, understanding, and approaches.
- Producing and sharing climate-relevant information so that it is accessible, useful, and equitable, remains a challenge.
- This case study highlights factors shown to be important in designing climate information services, specifically a seasonal farm advisory, while highlighting the persistent barriers such efforts face.

Australian National University | Institute for Climate, Energy & Disaster Solutions | Australian Centre for International Agricultural Research | Australian Aid

Knowledge is power...

... or so the saying goes. But information only becomes powerful if it is both relevant and accessible to those who need it. Climate change information dissemination and uptake faces significant hurdles in terms of comprehension and the appropriateness of the communication channels. For example, in the Pacific Islands, weather and seasonal climate forecasts are mostly provided by the national weather or meteorological services, but remote communities are often unable to access, understand, or even trust these forecasts (Chambers et al., 2019). As such, it is critically important to develop climate information services that reflect the needs and capacities of farmers. Our research project[1] in Papua New Guinea is working to understand how information from seasonal climate forecasts can best address the needs of farmers trying to build more adaptive and resilient agricultural systems.

Current Context

Country background

Papua New Guinea (PNG) is the world's third largest island nation, composed of the eastern half of the island of New Guinea and its associated off-shore islands. The landscape is heterogeneous, with high altitude areas of montane rainforest down to the lowland forests and wetlands, which also influences the weather patterns considerably.

There are nearly nine million people in the country, the majority of whom live in rural communities and engage in small-scale subsistence or cash crop agriculture. Rural subsistence-based communities are home to over 80% of the poor in Papua New Guinea. Particularly in rural communities in PNG, rates of literacy and numeracy are low, which affects the ability of rural people to access and understand information relevant to agricultural production and their livelihoods (Caffery and Hill, 2019). The strongly patriarchal nature of society and latent gender inequality also present constraints for women in rural areas to access land, water, seeds, fertiliser, credit, education, and training (Pamphilon and Mikhailovich, 2016; UNDP, 2019).

Food production system

Land-based, rainfed food production dominates in PNG, and mostly supports subsistence crops, with some cash crop production like coffee and cacao. The main crops include Irish potato, sweet potato, cassava, taro, maize, and bulb onion. The majority of land falls under some sort of customary tenure, where land cultivation by households is dictated at the clan level (Babon et al., 2014). Traditional roles, practices, and knowledge systems also feature centrally in PNG's smallholder farming systems (Cahn and Liu, 2008; Sithole et al., 2015).

In PNG, agricultural extension includes communication and learning activities for agrarian communities ranging from agronomy and cultivation, to business and marketing, to engineering and technology (Sitapai, 2012). While these activities largely fall under the purview of government agricultural and livestock agencies, NGOs and community-based organisations (CBOs), such as church-affiliated organisations (e.g. Lutheran Development Service, Salvation Army), also provide technical assistance and information, especially to groups within communities like women or the poorest households.

Climate change impacts

According to the IPCC, climate change is anticipated to be highly detrimental for people in Pacific Island nations, with major impacts related to sea level rise and shifts in rainfall (Nurse et al., 2014). Although temperatures are also projected to increase in the nearterm, precipitation shifts often have stronger influences on the agricultural sector. PNG is expected to experience more extreme rainfall throughout the year, as well as increasing variability of this rainfall within and between growing seasons. However, improving or enhancing the way in which climate risk management is incorporated into agricultural practises remains an ongoing challenge (ADB, 2011). Access to agricultural extension and climate information services can

[1] 'Informing climate-smart agriculture in PNG' is funded by the Australian Council for International Agricultural Research (ACIAR), and implemented by The Australian National University.

support this, having been shown to increase farmers' ability to adapt their practices to climate change (Juan, 2018).

Addressing the Challenge

Information solutions

Seasonal Climate Forecasts (SCF) are probabilistic projections of temperature and rainfall conditions that can be used to plan food production ahead of evolving seasonal climate conditions, provided three to six months in advance. Since the weather is inherently uncertain, SCFs also make it possible to demonstrate the confidence of an event occurring. For rainfall, our forecasts show the chance of having wetter, drier, or average conditions during a month or three-month period. While helpful, the SCF alone is often not enough to support better farm decision-making.

So what do farmers actually need? Farmers had their say during a series of farmer field days to demonstrate management practices in response to forecasts, held by PNG's Fresh Produce Development Agency (FPDA) and the National Agricultural Research Institute (NARI). The importance of rainfall information for decision-making was clear. Rainfall influences what can be planted, when, and where. One farmer noted:

"When there is rain above normal, the farm can be managed with better drainage systems to allow for excess water to drain out. Then planting can be decided. But when there is rain below normal, we need to introduce on-demand irrigation during the productive growth period of the crop or rather than wait for the usual rainfall to cultivate soil."

Farmers also noted that additional information about the optimal use of fertilisers, particularly organic options like manure and compost, based on the rainfall conditions is also important to improving management and adapting to changing conditions.

Forecasts and farmer feedback can be used to design *Seasonal Farm Advisories,* which translate short, medium, and longer-term climate forecasts, alongside agricultural production and market information, into accessible and understandable guidance for farmers to adapt their crop varieties and management practices. These advisories can identify specific crops or varieties that would fare best under above- or below-average rainfall, and suggest modifications to irrigation and fertiliser applications.

Social, cultural, and geographical considerations

Getting the content of climate information services right isn't the only thing. Climate information has historically been conveyed in ways that favour the technologically savvy or 'better-off' farmers, leaving most farmers without understanding of relevant climate forecasts (Ash et al., 2007; Caffery and Hill, 2019; Hoang et al., 2006). Understandably, there are a number of hurdles that we must understand better and redress to ensure that Seasonal Farm Advisories are effective and equitable.

While western science provides invaluable methods to inform decision-making, within communities in PNG, traditional knowledge is frequently used by people to make many similar environmental and weather predictions (Sithole et al., 2015). A household survey in our case study communities found that the majority of farmers rely on observations, and trust community and traditional leaders most, to inform their farm decisions. During one of the field trials, farmers also offered a number of traditional cues and responses. For example, one common way to predict a wet or dry season is by observing the life cycle of the Orycite beetle: the presence of larvae signify the arrival of the wet season, and the onset of dry periods in the coming months is indicated once the beetle reaches the adult stage and begin to use their wings to fly. Further research and trial is needed to determine how to integrate culturally-embedded environmental cues with modelled projections.

Men and women also have different information requirements in agricultural production and decision-making (Chanana et al., 2018). A social network analysis carried out for this project highlighted the stark gender contrast in information sharing networks. Women have stronger connections with family and friends, while men have more connections with media and community, agriculture, and government groups, suggesting greater engagement with formal institutions.

Geography also matters when determining how readily farmers can access information, and if it is relevant and timely. Our survey demonstrated that information sources and perceived challenges cited by farmers varied by province. In East New Britain, community and tribal leaders are particularly important climate information sources, while the Church was relatively more important in the Eastern Highland, and friends and family in Morobe province. These findings reinforce that the choice of communication channels and content has to be context-specific (Noske-Turner et al., 2014).

Pathway forward

The findings so far from this research project are valuable for determining the content, presentation, and modes of communication for farm advisories, so they cater to different user groups. We know traditional knowledge is important, tailoring advisories to suit men and women can overcome some gender inequities, and information products must reflect geographic differences. However, this deals mostly with the ‘what’ not the ‘how’. **We hope to draw on experiences from the broader community of practice to delve into procedural aspects, and discuss transferable lessons on how to move forward toward sensitive and inclusive climate information services.**

Discussion Questions

1. In your experience, what considerations are critical for climate information services to be tailored or co-designed to ensure they are accessible and of use to all stakeholders?
2. If the starting point is climate science and modelling, where do cultural and traditional aspects of knowledge integrate into climate information services?
3. What modifications to ‘process’ are needed to achieve successful co-design with communities, especially during pandemic restrictions and risks?
4. How can the dialogue between farmer engagement activities (e.g. field days) and seasonal climate forecasts be improved and incorporated into a Seasonal Farm Advisory?
5. More generally, what three recommendations would you give for translating scientific/technical advances into adoption and adaptation on farms?

Find out more about the project and partners here: https://www.aciar.gov.au/project/asem-2017-026

Case study prepared by Rachel S Friedman, a postdoctoral research fellow at The Institute for Climate, Energy, and Disaster Solutions, The Australian National University

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Case Study: Incorporation of technology to enhance aquaculture in a closed system

Contents

How can we bridge the gap between scientific and technological advances for climate adaptation in food production systems, and the implementation and adoption by farmers on the ground?

In this case study we will discuss the benefits of using technology to enhance aquaculture facilities that employ closed systems as a means of insulation from the natural environment. By becoming independent of the natural marine or fresh waters, many systems are less impacted by the changing climate, shifts in water chemistry, frequency of climatic events and the natural fluctuation in other organisms, such as algal blooms. However, this independence can come at a cost and require additional steps to maintain an efficacious aquaculture facility. This case study was produced in partnership with the Association of Commonwealth Universities (ACU) Climate Research Cohort. This provides a jumping off point to stimulate discussion on the challenges and opportunities for bridging such gaps in order to achieve transformative change and resilience in food production systems in the face of climate change.

Summary

- As the climate changes and we see increases in temperature and decreases in ocean pH level, it will become more difficult to confidently farm fish employing traditional methods, such as sea pens
- Given fish-based protein is a major source of nutrition in Southeast Asia, it is critical to ensure that fish farmers and their yields are protected in a changing climate
- Private companies and entrepreneurs are key to developing new technologies that can protect aquaculture. However, how are these new technologies able to support lower and middle income stakeholders
- Can not-for-profit organisations and or governments play a larger role in developing these new technologies to help facilitate the migration of aquaculture farms from business as usual to a more climate secured model, ensuring food security

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“Technology is a word that describes something that doesn’t work yet”, is a quote by Douglas Adams. In this case study I would paraphrase this as “Technology is a word that describes something that doesn’t work for everyone”. The key aim in this case study is to discuss some of the emerging technologies in aquaculture and highlight what problems these can solve, but at the same time indicate challenges small scale grass-roots stakeholders face in utilising technology.

Current Context

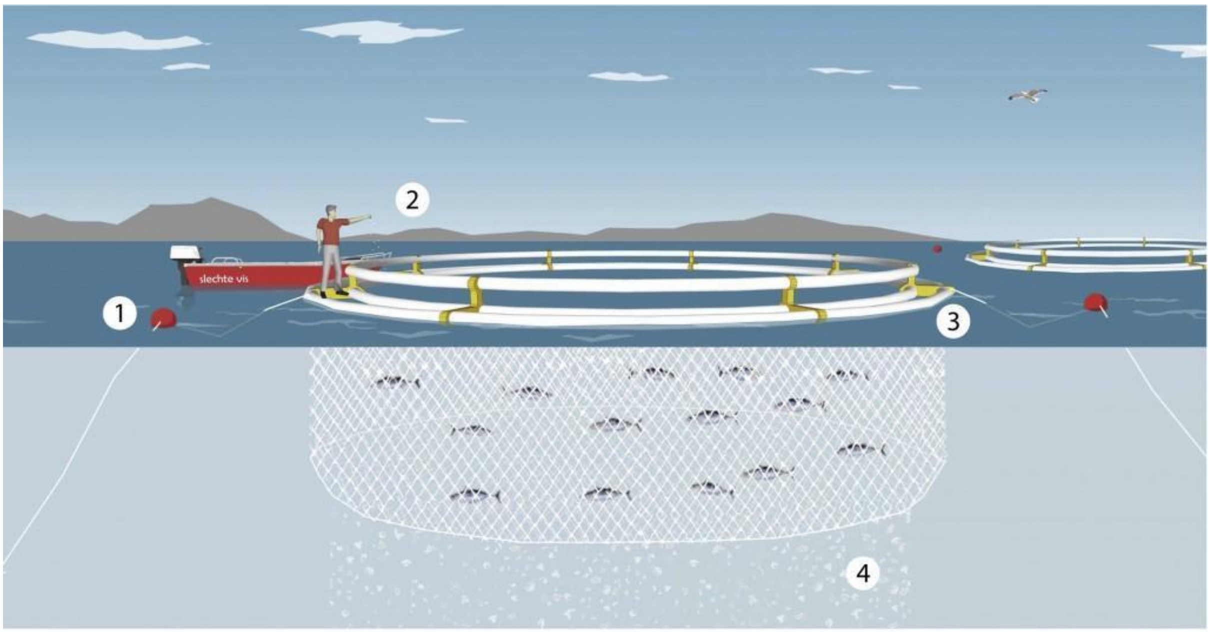
Country background

In the island state of Singapore, over 90% of all food is imported. The national government has recently stated that they want to see 30% of Singapore’s food produced locally by 2030 (30 by 30 program[1]), allowing Singapore to become more locally sustainable. For locally consumed fish, around 10% is farmed or caught locally, with the remainder imported (Shen et al., 2020). Therefore, improving aquaculture yields will be critical to achieve the 30 by 30 targets. There are several government facilitated aquaculture farms across Singapore, and some commercial farms supported in part by government grants or industry/academic partnerships. The ultimate aim is to increase aquaculture yields without becoming reliant on sea-pens, thus permitting Singapore to achieve its 30 by 30 targets.

Singapore’s aquaculture system

Historically many aquaculture facilities employed sea-pens to allow natural waters to flow through holding pens. These systems are popular as they simplify the housing infrastructure required, and they are the cheapest systems to install or scale up. However, they are also vulnerable to any changes to the local waters such as pH, oxygen availability or other natural disturbances, which can have negative impacts on fish stocks (De Silva and Soto, 2009). Many industrial-scale aquaculture facilities are moving away from open sea-pens to closed system recirculating systems (De Silva and Soto, 2009; Handisyde et al., 2006). The biggest advantage is that any variations in water quality of the natural environment will not impact the quality of water within the closed aquaria. Meaning that the predicted climate impacts to the waters surrounding Singapore will have a lesser impact on fish stocks grown in a closed system.

[1] https://www.ourfoodfuture.gov.sg/30by30



1. The cage is moored to the ocean floor 2. Fishemeal based feeds are added to the cages 3. Buoyant tubes keep the cages afloat 4. Fish faeces and waste fall through the cages

Image courtesy of goodfishbadfish.com.au[2]

Although Singapore's high level of industrialisation allows much of its domestic production to be farmed in these closed systems, many of its neighbours in the region are low to middle income countries with more limited access to this technology. This raises the question of whether technologies developed in Singapore, and elsewhere around the world, can be used both locally and internationally to ensure more resilient aquaculture across the wider ASEAN region (Morris et al., 2019). Protecting the industry in this region is particularly critical, as the growth in aquaculture over recent decades is about three times higher within ASEAN countries than outside[3], and this region being responsible for around 90% of the world's aquaculture products[4]. This protection has several aspects:

- Increased security to ensure food stocks are reliable
- An ongoing evaluation of the sustainability to ensure the region can maintain this global-scale effort
- Access to technologies to protect the industry from the worst impacts of climate change as well as enhance the first two points

Addressing the Challenge

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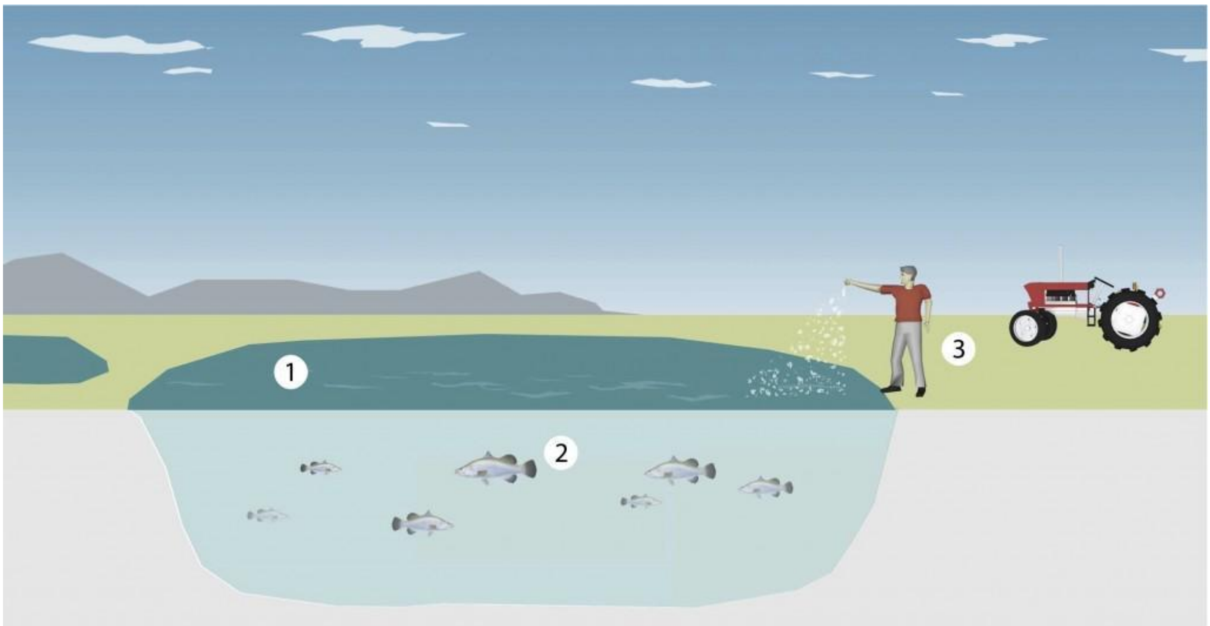
[2] http://www.goodfishbadfish.com.au
[3] https://tinyurl.com/6jrkyefu
[4] https://tinyurl.com/9xejncve

Closed system aquaculture

Moving aquaculture onto land insulates these systems from the worst impacts of climate change (De Silva and Soto, 2009). However, the costs are higher and there are still risks of disease and poor water quality that affect food conversion ratios or even entire harvest feasibilities. Closed system aquaculture is an attractive alternative. Several industrial stakeholders have led the way in developing these closed systems, which reduce the interactions with external factors, and therefore reduce the chance of biological contamination. This approach requires a dedicated effort in aseptic techniques to ensure biosecurity of the stock flora and fauna, while also relying heavily on emulating natural environments in which multiple trophic phases exist in one system. A substantial accomplishment if this fine balance can be successfully achieved.



1. The pond or tank exists in a closed system 2. Species including barramundi are grown using this system 3. Feed is added

Image courtesy of goodfishbadfish.com.au[5]

Another approach is to shift away from a reactionary solution to a more proactive stance. By constant surveillance of the aquaculture systems, it is possible to observe the evidence of infection before a major outbreak or mortality event occurs. This can be achieved through constant motion capture of the fish stocks, and developing baseline behavioural statistics. Should a particular batch show lethargy, for example, they can be examined before an outbreak. Furthermore, recording and examining other physical and chemical data can

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[5] http://www.goodfishbadfish.com.au

inform on various aspects of the fish health. For example metabolic activity, lethargy or other important signals such as oxygen depletion can be observed using conventional probes, cameras, or meters. permitting the efficacy of each harvest to be assessed and optimised to increase sustainability. Another example is the monitoring of feed and nitrogenous waste concentrations, permitting an assessment of the feeding efficacy and waste generation. This will allow fine scale changes to be made to limit food loss and subsequently increase water quality.

Biggest barriers: the cost and complexity

Cost is a major issue facing many grassroots aquaculture facilities. The move away from the natural water bodies requires substantial investment. Moving water is not cheap and will drive up maintenance costs. Even once these smaller establishments move to the land-based closed systems, they will likely be unable to employ suitable aseptic techniques in their daily operations, leading to mass mortality and ultimately the failure of this attempt at climate change adaptation. That is, unless these technologies that currently do not work for everyone are simplified and made affordable to a wider community. This can be achieved through allowing 'at-cost' access to these technologies, permitting smaller scale operations to employ camera based operations, or internet controlled water quality monitoring, even cloud based microbiome and probiotic analyses of the closed systems. Another possible solution to putting technologies in the hands of lower income farmers, is to allow shared facilities and costs within the aquaculture industry. Might allowing a lower income country use of surplus equipment not stimulate the propagation of this technology as well as improve yields for all. All of this technology is currently feasible and being developed by larger companies and well-funded governments. However, unless it is priced and targeted at a rate feasible for the entire aquaculture community, then we risk seeing the impacts of climate change and a decline in aquaculture yield, disproportionately affecting the lowest income nations and farmers (Barange et al., 2018).

Pathway Forward

How do we get these new technologies into the hands of low and middle income farmers? Given that the majority of these new technologies are developed by private companies, they have a significant intellectual property investment in these technologies. This is a hurdle lower income farmers face. However, if governments, not-for-profit organisations, and other NGOs are able to push new technologies to the market, it is feasible that the IP can be waived allowing the technologies to flow across border and income boundaries, resulting in greater food security throughout the region.

Discussion Questions

1. What are the main hurdles faced by aquaculture companies, with regards to the impacts of a changing climate.
2. If newer technologies were freely available to aid stakeholders in their efforts, would lower income farmers adopt these new approaches?
3. What actions do farmers want to see from their governments, and how will these help to secure food supplies in a changing climate?
4. Is adopting scientific and technological discoveries a realistic aim for smaller or lower income stakeholders if IP was to be waived?

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Case Study: The potential of underutilized crops to improve climate resilience and to promote food and nutrition security in Sri Lanka

Contents

How can we bridge the gap between scientific and technological advances for climate adaptation in food production systems, and the implementation and adoption by farmers on the ground?

Neglected and underutilized Crops (NUCs) provide effective crop solutions to improve food and nutrition security while building resilient food systems in the face of climate change. This case study examines opportunities for improving NUC cultivation and value chains in Sri Lanka. Furthermore, major constraints, and the research and policy needs to bring NUCs into mainstream agriculture, were studied. The case report is based on information gathered in a series of stakeholder meetings that were held in person, through online platforms and social media. This case study was produced in partnership with the Association of Commonwealth Universities (ACU) Climate Research Cohort. This provides a jumping off point to stimulate discussion on the challenges and opportunities for bridging such gaps in order to achieve transformative change and resilience in food production systems in the face of climate change.

Summary

- Sustainable intensification of neglected and underutilized crops present potential climate change adaptation/mitigation strategies that can be effectively integrated with food production and national development policies.
- NUCs mainstreaming connects health, agriculture and economic growth and thereby produce strong synergies between economic sustainability, healthy environmental policies and human health.
- Helping smallholder farmers to increase NUC cultivation for consumption is only the start point but NUC mainstreaming needs more systematic, long-term plans
- However, the systems in place are inadequate to facilitate cross-sectoral integration, and breaking silos between institutions involved in research and development, policy formation, market forces, and the local agriculture and farming sector. Lack of meaningful collaborations significantly delay achieving targets for NUCs promotion.

University of Peradeniya

Youth for Climate Action

Postgraduate Institute of Science University of Peradeniya

Board of Study in Plant Science, PGIS

The Association of Commonwealth Universities

"Feeding" to "Nourishing"

NUCs are nutritious, climate resilient, economically viable (in the right setting) and adapted to local conditions. Local farmers have effectively used these crops in their traditional farming systems for over 3,000 years to develop resilience and adaptive capacity to extreme weather. Over 1,170 edible plant species are recorded in Sri Lanka. Scoping, validation and prioritization programs conducted locally, reported 58 prioritized varieties or landraces of 28 NUC species, along with information on nutritional composition and ethnobotany. These NUCs species can be effective crop solutions to develop climate smart agriculture and potential leverage points for addressing malnutrition from a food system perspective.

Country Context

In Sri Lanka, agriculture contributes 10% of the national gross domestic product (GDP), and is the main livelihood of rural people, who represent over 80% of the population. Over 65% of the land in the country is utilized for agriculture. Out of the economically active population, 43% is engaged in agriculture and 37% of them are women (FAOSTAT 2014). Local food production accounts for approximately 85% of domestic food requirements, and over 80% food is produced by smallholder farmers cultivating less than one acre. The nation is self-sufficient in rice, the main staple for both produce and seeds but depends on imported seeds for many other crops. Furthermore, local commercial agriculture imports almost all inputs including fertilizers and agrochemicals therefore, liable to both local and global economic and political instabilities.

Food production systems and food security

Food available and affordable for the poor is energy-dense but nutrient poor. Food production has increased significantly since the green revolution, whereby prevalence of undernourishment in South Asia dropped from 25% to 16%. Nevertheless, national average energy consumption in Sri Lanka is 2,094 Kcal which falls close to "low" based on the standards set by the International Food Policy Research Institute (IFPRI). Sri Lanka ranks moderate (10.0-19.9) in the Global Hunger Index, but the Calorie deficit in the population is the highest recorded in South Asia. Over 15% of the children under five are food insecure and Sri Lanka is among the 10 countries in the "very high category" for prevalence of wasting. Protein-Energy Malnutrition (30%), and vitamin A deficiency (VAD, 36%) are among the major conditions resulting in hidden hunger and malnutrition in the population (FAO, 2018). Sri Lanka ranks 77th in the Global Food Security Index where poor protein quality, low diet diversification and lack of food safety net programs negatively affect the ranking.

Climate change impacts

By the year 2050, 1.2% GDP loss due to climate change is predicted in Sri Lanka. Several districts in Sri Lanka are "Highest Risk Disaster Hotspots" for hydrological hazards including floods, cyclones, and landslides. Over 12% of the cultivated rice extent is currently not harvested due to terminal droughts (Weerakoon et al., 2010). Dry spells increase evaporative demand that results in upward movement of salt increasing subsurface salinity and affecting more than 45,000 hectares of agricultural land in the country (Mapa et al., 2003). Furthermore, not more than 34% of local cropland is irrigated (Biradar et al. 2009). Heavy dependence on rain water and natural resources makes the local agriculture exceedingly vulnerable to climate extremes.

The above discussion highlights two significant gaps in the local agriculture and food systems. Firstly, the Production gap: although the country has self-sufficiency in rice, the rice yields are already approaching the maximum attainable yields leaving limited room for further improving crop productivity. At the same time food accounts for 13% % of the merchandise imports to the country in 2017 highlighting the importance of investments on food diversification and increased production of supplementary food. Secondly, nutrition gaps between what foods are grown and available, and what food is needed for a healthy diet. Responding to these dynamics requires combining all possible levers of change to foster a transformation towards more productive and resilient food systems.

NUC Targets

This case study identified seven main targets whereby NUCs mainstreaming can achieve climate resilience, and food and nutrient security.

1. **Nutrition dense alternatives**. Having self-sufficiency in rice, realizing the same with supplementary food crop production is mandatory to achieve food and nutrition security. An average Sri Lankan consumes less than half of the recommended amount of fruits and vegetables. The 58 priority NUCs with the nutritional profiles made available can be used as crop solutions to address these health issues.
2. **Climate smart crops and sustainable agriculture systems.** Climate smart agriculture can link increased productivity with enhanced resilience and a reduced carbon footprint. NUCs can promote zero carbon natural farming using indigenous crop portfolios and mixed cropping systems. This creates healthy ecosystems and agriculture landscapes that can provide vital ecosystem services and sustainable harvest.
3. **Develop local food chains, food systems and food sovereignty**. Sri Lanka imports twice the amount of vegetables and fruits that it exports, and one-third of the vegetable seeds the country uses. Dependency on imports for fertilizer, agrochemicals and seeds makes local agriculture vulnerable to climate and economic instabilities. NUCs can promote local technology and local seeds to develop local food chains and thereby increase income for rural communities and in the long run ensure food sovereignty.
4. **NUCs are effectively used in increasing cropping intensity and productivity.** On average 55% of the dry zone land cultivated in the major season is abandoned during the rest of the year due to water scarcity. Introducing water efficient farming practices combined with less water and input demanding crops such as NUCs can increase cropping intensity from the current 0.9% to a potential 2% in the dry zone. NUCs including land races of cowpea, sesame and horse gram, and finger millet were successfully cultivated in additional 2nd (minor) and/or 3rd (mid) seasons using excess moisture from the main cultivation season to achieve higher production. This practice is further advantageous when NUCs are used for crop rotation, resulting in enhanced soil properties and fertility, and reduced pest pressure in these agricultural systems.
5. **NUCs to capitalize on underutilized resources.** NUCs can be used as crop solutions to increase profits from marginal or degraded lands. For example, traditional rice varieties were cultivated in marginal paddy lands with minimum inputs.
6. **Rural empowerment.** With rice self-sufficiency secured, the country needs to diversify production structure by strategically focusing on NUCs to move towards high-value agriculture, developing new consumer products and to promote agricultural exports. Thereby NUCs can be a crop solution to increase income for the rural sector. Such opportunities for income generation will motivate youth to remain engaged in agriculture.
7. **Women's empowerment.** Cultivation and utilization of NUCs is associated with subsistence production by women in traditional farming. Increasing NUCs cultivation therefore, creates significant opportunities for women promoting gender equality and women empowerment.

Pathways Forward

However, there are still steps to be taken and barriers to overcome. The pathways forward to increase NUCs cultivation and production can be broadly categorized into four clusters:

1. Awareness building, increased access to information and efficient extension services

Introducing NUCs will require a restructuring of existing farms for efficient resource usage, enhanced sustainability and for maximizing profits. Providing adequate extension services on water efficient practices and soil conservation measures such as SALT farming, contour farming, live fences, crop rotation and Good Agricultural Practices (GAPs) is important. Although smallholder farmers are generally aware of these practices, most have limited capacity or interest in practical applications of the same. Most are not knowledgeable to do an effective cost-benefit analysis prior implementation of these practices. Reinforcing public and private extension services is therefore essential to overcome the barriers of lack of knowledge usage.

Promote Nutrition education. Public education is vital to promote nutrient–rich foods and NUCs usage. The integration of nutrition education and behavior change strategies in primary, secondary and tertiary education programs and research and development in health and nutrition are important.

2. Climate preparedness

Agro-climatic advice. NUC farmers often cultivate in marginal farms in climate vulnerable conditions. With access to accurate weather information, farmers can make informed and timely decisions about crop choices, timing of agronomic practices and more importantly on investing.

Climate risk insurance. Risks are inherent to NUC farming because these crops are often grown in vulnerable conditions. Risk-averse farmers underinvest in cultivation. Crop insurance helps farmers to cope with financial losses caused by unpredicted extreme weather. Although some schemes are in place, the application rates are low due to lack of awareness, farmers unconvinced of the benefits, or the existing schemes not catering to NUCs.

Improved, climate resilient seeds. Sri Lanka imports 33% of vegetable seeds and most of these vegetables are temperate species where there is no breeding focus in the tropical countries. Investing in NUCs breeding programs for developing improved, resilient planting material can provide long term crop solutions for climate mitigation and income generation.

3. Value chain development and clever ways of financing

Financial and non-financial incentives for on-farm and off-farm operations. Farmers show positive adoption rates when financial and advisory support is provided. Investment in productivity and sustainable practices is financially difficult for smallholder farmers and low-income producers. Thus, flexible credit programs sponsored by the state or private sector need to be introduced.

NUCs production and value chain management need to be technically sound to meet market trends and to cater to the emerging nutrition and healthy food demand. NUC integration for high-value production, processing and value addition require structural shifts in local agro-ecosystems and along the value chains. However, inclusive planning and implementing cross-sector programs are nonexistent or weak in the current policy framework structure. Linking the different actors, including farmers, state actors, and the private sector, is critically important.

Flexible systems to obtain local and international quality standards such as Sri Lanka Standards Institute Certificate, HACCP, Global GAP certificate, Sri Lankan GAP certificate, USDA organic certification, EU organic certification, and ISO 22000. These certificates create new markets and enable local products and agripreneurs to enter the international markets.

4. Technology integration

Introducing low cost, locally innovated, and appropriate technologies to increase productivity and resource use efficiency of farming systems. Labour, land, water, and other inputs are limitations for NUCs expansion. Technology integration can overcome some of these issues. Technologies to increase productivity and quality include cultivation tools, crop cultivation methods under poly tunnels, use of drip irrigation systems, postharvest management techniques, cold storage and cold chains, processing machinery, packaging and transportation. However, farmers have different levels of interaction with technology. Thus, to introduce new or versions of already existing technologies and tools would require inclusive, well-designed strategies for technology development and delivery.

Limited technological know-how and lack of **use of IT in farming activities** slow knowledge advancement of Sri Lankan farmers and agri-entrepreneurs. This in turn significantly reduces horticultural yields when compared to other emerging agri-economies in the region such as India, and Bangladesh. In those countries average yield is 20-30% higher compared to Sri Lanka. Thus, effective training programs and uplifting and promotion of agriculture education programs are essential to empower farmers. The programs can specifically target youth.

Innovation hubs and centers of excellence for research and extension of NUCs mainstreaming. Joint initiatives by private and public sector stakeholders with the involvement of farmers and other actors in the value chain will enable creating collaborative platforms and national and international networking to deliver appropriate, new technologies quickly. Furthermore, negligence by researchers and policy makers has resulted in genetic erosion as well as loss of local knowledge of NUCs. Discovery and integration of traditional knowledge can enhance innovation processes.

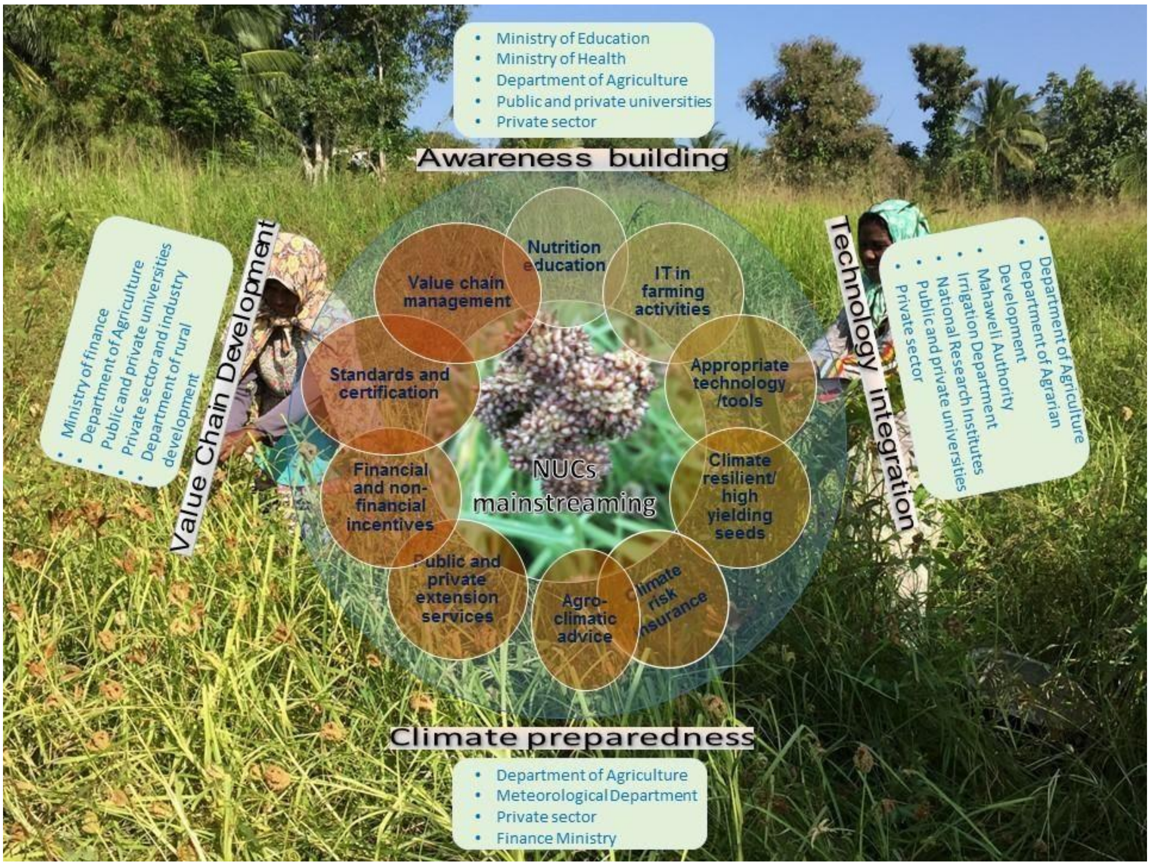

Figure 1. NUCs mainstreaming needs to break silos between the development of appropriate interventions, and communication and dissemination

Stakeholder engagement

The case study engaged with public and different stakeholders involved in the process of NUC mainstreaming. Engagement activities were organized and implanted through the youth activity group "Youth for Climate Action" (https://yfca.sites.pdn.ac.lk/home). The group was initiated as an operational arm with the participation of undergraduate and postgraduate students of the University of Peradeniya. Public awareness raising activities were organized and opportunities were created for the general public, administrators, scholars, academia and research to share perspectives, experiences and results from scientific evaluations to develop a strong knowledge base on NUCs. Wider community engagement was reached through online platforms and social media[1].

[1] https://www.facebook.com/youthforclimateaction.uop/, https://twitter.com/Youth_4_Climate?s=09, https://www.youtube.com/channel/UCvJmi7thq_OcPklGTAebUhQ, https://www.linkedin.com/company/youth-for-climate-action-uop

The case study identified twenty progressive, NUC farmers as nodal farmers from nine administrative districts. Mini-seed packets containing four NUC cereals including finger millet (*Eleusine coracana*), Codo millet (*Paspalum scrobiculatum*), Pearl millet (*Pennisetum glaucum*), and Foxtail millet (*Setaria italica*) were distributed among the farmers along with a pocket guide book describing NUC cultivation, agronomic practices, processing and value addition. The nodal farmers will multiply and distribute the seeds in their communities. The program was initiated as a pilot project and implemented in collaboration with the Field Crop Research and Development Institute (FCRDI), Department of Agriculture, Sri Lanka. FCRDI and the research group led by the author will monitor progress of the program.

Sustainable intensification and conservation of NUCs needs urgent action in the above four areas. There is a growing realization globally and locally that agriculture must diversify and NUCs offer interesting possibilities to develop sustainable and economically viable production systems for advancing agricultural development and climate resilience. However, lack of interaction across sectors including agriculture, nutrition, education and market forces, and among stakeholder groups (farmers, researchers, value chain actors, decision makers) is a key limitation in achieving synergies and collaborative platforms for mainstreaming of NUCs.

Figure 2. The label of the mini seed packets distributed among nodal farmers for multiplication and distribution. The caption translates as “Plant these seeds, share with others and contribute to food security. Project initiated by Youth for Climate Action”.

Discussion questions:

1. What role can NUCs play in achieving food and nutrition security?
2. How can small-scale, environmentally friendly farming contribute to food and nutrition in the global south?
3. What knowledge gaps need to be immediately addressed for NUCs mainstreaming?
4. What policy transformations and societal changes will promote NUCs production and consumption?

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Climate resilient food production systems and the SDGS: a multifaceted relationship

Contents

This write-up discusses the role of climate resilient food production systems in achieving the Sustainable Development Goals. It looks at the challenges and opportunities in this area through a cross-case study comparison carried out through the Research to Action (R2A) Project on "Breaking silos for food production systems innovation and improved climate resilience" in partnership with the Association of Commonwealth Universities (ACU) Climate Research Cohort. The case studies arise from Nigeria, Papua New Guinea, Singapore and Sri Lanka, and seek to answer the question:

How can we bridge the gap between scientific and technological advances for climate adaptation in food production systems, and the implementation and adoption by farmers on the ground?

Summary

- Food production systems are inextricably linked to the SDGs and provide both opportunities and challenges to advance them.
- Climate resilient farming and aquaculture systems are strongly connected to more than half of the SDGs and thus have a role to play in accelerating progress towards them.
- The specific SDGs that are important in bridging the present gap between the technological advances and their actual usage by farmers include SDGs 4, 5, 7, 8, 9, 10.
- Maximizing the positive synergies amongst the relevant SDGs while balancing the potential trade-offs is necessary for achieving SDG Targets as many are interlinked.
- The pathways to achieving SDGs can be diverse amongst different regions and it therefore requires customized solutions to accelerate their achievement.
- Partnerships for the goals (SDG17) is of special importance due to its impact on multi-stakeholder partnerships to share finances, knowledge, expertise and technology, particularly for the benefit of developing nations. Support of this nature would be especially beneficial for increasing the use of innovative climate adaptation strategies by farmers.

The need for climate resilient food production

The total global food demand is expected to increase by 35% to 56% between 2010 and 2050, with this range further widening in projections that take climate change into account (van Dijk et al., 2021). The Intergovernmental Panel on Climate Change (IPCC 2018) has emphasized that climate change will impact all aspects of food security, creating the need for greater focus on climate resilient food production systems. Climate resilient agriculture refers to the ability of an agricultural system to anticipate, prepare for, adapt to, absorb, and recover from the impacts of climate change and extreme weather through short- and long-term adaptation and mitigation strategies. The resilience described here can be further enhanced by ensuring transparent and inclusive participation of multiple actors and stakeholders in decision-making and management processes (Alvar-Beltrán, et al., 2021).

The Sustainable Development Goals (SDGs)

In 2015, at a historic United Nations Sustainable Development summit, world leaders adopted the 2030 Agenda for Sustainable Development and pledged to achieve a set of 17 goals by 2030 with the general aim to end extreme poverty, reduce inequality and protect the planet (United Nations, 2015). These Sustainable Development Goals (SDGs) are defined by 169 Targets and 231 unique Indicators, which have a baseline value that is used to compare the progress made by each SDG. The SDGs' act as a main reference point for national level development policies and hence have a strong impact for promoting sustainable development at national levels.

Food production systems and the Sustainable Development Goals

Food production systems are inextricably linked to the SDGs and provide both opportunities and challenges to advance them. This link is further reinforced due to the vulnerability of food production systems to the effects of climate change, coupled with their role as a driver of climate change.

The scale and sheer ambition of the SDGs require innovation for their ultimate attainment. This is true in the case of agricultural innovation, and its widespread adoption would be a key enabler for many of the related SDGs to be achieved. It is also important that the innovations in question are environmentally sound, socially inclusive, and economically viable in the context of the implementing country. Therefore, there is merit in looking at country specific scenarios as was done through the case studies in the present R2A study. The case studies used are given below in alphabetical order of the country of origin.

- Improving efficiency in adaptation of fish farming to climate impacts in Nigeria by Dr. Oyediran Olusegun Oyebola
- Seasonal farming advisories in Papua New Guinea by Dr. Rachel Friedman
- Incorporation of technology to enhance aquaculture in a closed system (Singapore) by Dr Stephen Summers
- Potential of underutilized crops to improve climate resilience and to promote food and nutrition security in Sri Lanka by Dr. Chandima Ariyarathna

This write-up had two objectives. Firstly, to look at the linkages between climate resilient food production systems and the Sustainable Development Goals. This first objective was met by analysing the case studies which document country specific examples from the farming and fisheries sectors and mapping them against the SDGs. Secondly, it aimed to look at the specific SDGs that are important in bridging the present gap between the technological advances for climate adapted food production systems and their actual usage by farmers and fishers.

Relationship between the SDGs and the climate resilient agricultural systems

Figure 1 below maps climate resilient food production systems against the SDGS in the context of the four case studies above.

As can be observed from Figure 1, climate resilient farming and aquaculture systems are strongly connected to more than half of the SDGs and thus have a role to play in accelerating progress towards them. It should be noted however that this is not an exhaustive list of linkages as only the direct linkages of these sectors to the SDGs are highlighted in this write-up, and that too through four country specific case studies. Furthermore, many of these SDGs themselves have synergies with one another leading to often surprising alignments that are not mentioned here and thereby contributing to additional complexities in number and depth. For example, food security and peace are often mutually reinforcing and thus through SDG 2, innovations in food systems can have a positive effect on promoting 'just, peaceful and inclusive societies' (SDG 14). Therefore, potentially an even larger number of SDGs could relate to climate resilient farming and aquaculture sectors. However, the trade-offs between the SDGs should also be taken into account and balanced where possible. An oft provided example is the trade-off between forest conservation under SDG 15 and development of agricultural lands to achieve SDG 2 on 'zero hunger' which requires a balance between environmental protection and food security (Campbell et al., 2018).

Addressing the challenges

According to figure 1, certain Goals such as SDGs 2, 3, 8, 10, 12 and 13 relate and span across all four case studies, while others such as SDGs 9 and 17 were connected to just one or two studies. Among the case studies, the aquaculture technology related study from Singapore had dissimilarities with the rest due to the relatively higher cost and technology requirements of the adaptation intervention and also as it was the only country in this study from the Global North. However, the Singaporean case study did address the potential issue of uptake of aquaculture technology by developing countries and/or low-income stakeholders - for instance by cutting costs through waiver of intellectual property rights.

The specific SDGs that are crucial to bridging the present gap between the technological advances and their actual usage by farmers and fishers included several that were not mapped under figure 1. For example, it includes quality education (SDG 4) and affordable and clean energy (SDG 7), where the former contributes to greater human capacity development and acceptance of new technology, while the latter can be a necessity for innovative advances in climate adaptation. Another important SDG in this regard is gender equality (SDG 5) as many females in developing nations are a marginalized group with regard to education, and often do not enjoy equal property and economic rights. SDG 8 on decent work and economic growth as well SDG 9 on industry innovation and infrastructure would be necessary for greater acceptance and availability of innovative technological solutions in the agriculture sector. Other than these, the SDGs on climate action, life below water and life on land were important (SDGs 13, 14 and 15) to lay a foundation in this area.

The disparity between the perspective of SDGs on food production systems in the Global North and Global South was seen even within the small cohort of case studies used. According to Campbell et al. (2018) the Global South tends to focus on food production, food security and adaptation, while the Global North is more focused on mitigation strategies and the environmental impacts of food systems. This further hints that the pathways to achieving SDGs is also diverse amongst different regions and it therefore requires customized solutions.

Though there is an interest in climate resilient agriculture, many developing nations have financial and capacity related challenges in implementing adaptation strategies. This brings to the forefront the need to achieve SDG 17, where global partnerships are strengthened in order to further sustainable development. The pathways include financial development assistance commitments and other multi-stakeholder partnerships to share knowledge, expertise and technology, particularly for the benefit of developing nations. Thus, while mainstreaming SDG 17 has the capacity to accelerate progress in all SDGs, it would be of special significance for bridging the gap of technology and farmer acceptance of climate resilient food production systems.

The 2030 Agenda was initiated to end extreme poverty, reduce inequality, and protect the planet. It pledges to 'leave no one behind' in realizing the SDG targets. Climate resilient food production systems, if properly undertaken and with adequate support particularly for developing nations, have the capacity to achieve this and much more.

Discussion Questions

- Which further SDGs can be directly supported by filling the innovation adoption gap for climate resilient food production systems?
- What is required to ensure the maximizing of the positive synergies amongst the relevant SDGs while balancing the potential trade-offs?
- What factors would further enhance national governments mainstreaming relevant SDGs into their national policies on food production systems?
- What are the barriers present in progressing towards SDGs that support bridging the gap between technology advances in climate resilient agriculture and their subsequent usage by farmers and fishers?
- How can the responsibility of achieving targets under SDG 17 (partnerships for the goals) be further encouraged in the global agenda?

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