Evaluation report:
Enhancing Adaptive Capacity of Small and Marginal Farmers of Purulia and Bankura Districts, West Bengal to Climate Change

Implemented by DRCSC and Supported by NABARD

March 2023

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Executive Summary

The program "Enhancing Adaptive Capacity of Small and Marginal Farmers of Purulia and Bankura Districts, West Bengal to Climate Change" has introduced eight key interventions pertaining to food and water security, diversified income, and better livelihood to improve adaptive capacity and infuse resilience to climate change among small and marginal agrarian households. We have undertaken an evaluation study to gain an understanding of the development and its progress. We compared and evaluated the pre-project background of the intervened villages and the status after the implementation employing detailed research on existing documents followed by on-site interviews, group discussion, and rigorous field surveys.

It revealed a few major observations that suggested the creation or rejuvenation of small or large water structures for better availability, facilitation of agricultural activities through weather station-generated agro-advisory, efficient agricultural practices, promotion of social forestry for easier access to food, fuel, and fodder, the revival of the traditional granaries and community seed banks through women's self-help groups (WSHGs), livestock rearing for additional income generation. Strong social cohesion among the group members, a sense of responsibility, and a feeling of community ownership around assets have also been noted. Altogether, the indicators allowed us to gain key insights that emphasized their better food and nutritional security, higher water access, enhanced and diverse income, and alleviated poverty level. The intervention made them better prepared, enabled collective decision-making, inculcated adaptive capacity, and instilled resilience to withstand climate precarity.

Keywords: Climate Resilience, Self-help Group, Adaptive Capacity, Livelihood, Small and Marginal Farmer, Hyperlocal Weather station, Water security, Food and Nutrition Security

Introduction:

Drought-related vulnerabilities have risen in recent years and intensified especially in rainfed semi-arid ecosystems of eastern India and endangered the livelihood of many. Pertinently, rainfed agroecosystems also bear the brunt of the historical injustice of being underprivileged (Tozzi et al. 2022). The narrative of water scarcity has fueled the high consumption of groundwater, unplanned and sporadic construction of irrigation structures, or helped to gain subsidies through political channels (Gogoi and Tripathi 2019; Mohan 2015). It eventually created serious mismanagement in agriculture and deprived some regions to tap their full potential. The Green revolution agriculture, blind to the co-adapted local agroclimates and crops, vehemently promoted a model that entirely relied on high inputs, e.g., high-yielding seeds, fertilizers, and a sure supply of groundwater (Shiva 1991; Ray 2022). As a result, a few regions arguably received the benefits of production hikes while many were left out of the race and became less impoverished. Besides, environmental footprints were even unfathomable and its ghosts continue to haunt Indian agriculture even after several decades of actual initiation (Ray 2022). The positive outcomes of the GR (at least in terms of production) were observed to be geographically patchy and concentrated in the regions with improved infrastructures (Ray and Chakraborty 2021). Because of its overarching effect, some regions especially rainfed, drought-prone semi-arid regions underwent a seminal change in their agrarian activities, that perhaps changed their cropping pattern, moulded the trajectory of subsistence, endangered their livelihood, and caused vulnerability to spurt.

Climate change is the recent menace to the grave crisis. The impending threats of climate change affect water resources, constraining food security, and human health, and impacting biodiversity (Field and Barros 2014). Agricultural production worldwide has been adversely affected by increasing temperatures, changes in precipitation, and the extreme events associated with climate variability (Chen and Muller 2018; FAO 2016). It threatens people's lives through impacts on livelihoods, such as decreases in crop production, food insecurity, and destroyed homes (Barrios et al. 2008; Challinor et al. 2014). The interaction of climate variability with food security can multiply malnutrition (Ramin & McMichael, 2009). The impact is likely to be high on the rural, poor, and marginalized populations (Kasperson 2001; Szabo et al. 2016).

The background of cultural geographic regions

Purulia and Bankura districts are geographically situated in the semi-arid rainfed region. Relatively sparse vegetation and continued deforestation aggravated topsoil erosion after heavy rainfall owing to the impervious layer and permeability barriers, which also restrict the percolation of rainwater. The inability to conserve rainwater and lessen erosion renders agriculture difficult with only one crop, rice, annually during the Kharif season. The region also experiences very high temperatures and heat waves in summer, which further restrict the scope of pre-Kharif farming. Severe water scarcity and erratic weather compounded by the absence of sustainable farming practices further impede Rabi crop cultivation.

The population is composed of historically marginalized communities (Scheduled Castes, Scheduled Tribes, and Other Backward Classes) who used to cultivate low-water requiring crops in the pre-Green Revolution periods. Over the last three-four decades, they have been transformed into nearly a rice-centric economy owing to the gradual adoption of Green Revolution agriculture. With poor

adaptive capacity, educational attainment, and prospects of being temporary wage laborers, many distressed households depend on remittances sent by migrant members engaged in the formal or informal sectors. Studies by many authors (Islam and Winkel 2017; Kasperson 2001; Szabo et al. 2016) across the world on developing countries suggest that their distress and vulnerability are predicted to exacerbate with the changing weather conditions unless focused interventions are planned and implemented to ensure food security, economic well-being, and social welfare thus instilling resilience to climate change.

Key Interventions:

The program, "Enhancing Adaptive Capacity of Small and Marginal Farmers of Purulia and Bankura Districts, West Bengal to Climate Change" aimed to introduce interventions to improve poor resilience to climate change and adaptive capacity among small and marginal agrarian households. The project is supported by a grant from Adaptation Fund through the National Bank for Agriculture and Rural Development (NABARD). The eight critical interventions have been planned and implemented by the DRCSC in Kashipur and Chhatna blocks since 2015 to reduce the vulnerability, to enhance the adaptive capacity and resilience to climate change of 5000 households mostly consisting of the small and marginal farmers of the Puruliya and Bankura district.

1. The use of Geoinformatics combined with local knowledge to improve water harvesting and micro-irrigation structures.
2. Establishment of hyperlocal weather stations (for an area of 10 sq.km.) to issue more accurate weather forecasts and subsequent agro-advisory to fine-tune the decision-making abilities of the communities.
3. Support vulnerable communities' transition towards drought-resilient farming and improve their food and nutrition security by increasing water availability and productivity of agricultural land.
4. Promote social forestry with multiple native variants of trees to improve biodiversity, and increased access to food, fuel, and fodder.
5. Revive the use of traditional grain/seed banks through women's self-help groups (WSHGs) to supplement food security and store excess grain.
6. Collaborate with multiple stakeholders to develop a holistic, multi-pronged approach to program design and implementation.
7. Form women self-help groups (WSHG) and other purpose-driven groups with women at the helm to promote and implement the agricultural and lifestyle changes for developing climate resilience.
8. Design interventions in a way that evokes a sense of community ownership around the program and promotes sustainability.

Objective of the study

The present report evaluated the achievements, detects the constraints, compared the findings from a pre-implementation survey of beneficiaries held in 2015 with those of post-implementation survey held in 2023, and identified lacunae and suggested future actions. In a nutshell, the study's primary objective was to assess the major projected achievements in water security, reduce hunger days, national

and food security, reduced migration, reduced loans from moneylenders and improved purchasing power.

Methodology:

We employed a mixed-method approach to evaluate developing adaptive strategies. It consisted of formal or informal interviews with the key personnel/leader and focus group discussions with a set of questionnaires. Alongside, in order to test and validate the tangible benefits confirmation of key visible indicators in the field or elsewhere has also been made (figure-1a-d). The surveys were conducted in almost 90% of the beneficiary villages and interacted with 60-80% of the households (key male/ female members, SHG leaders, senior members, facilitators, other informants, etc).

A. Review of existing literature (study report, papers, summary, or other kinds of documentation by DRCSC) to gauge the nature of the problem, the background of the interventions, their local purpose, functions and beneficiaries, and mode of implementation and operation.

B. Focused group discussion (FGD)

FGDs were conducted at village(s) individually with one women's self-help group (WSHGs) or combining two adjacent groups wherever such entities were available. A set of structured questions pertaining to recent dietary diversity, agricultural practice, water provisioning, migration dynamics, income security, etc were designed and asked. The answers were recorded and verified.

C. Personal interview

Similarly, a few personal interviews were conducted informally at selected villages. The informants were mostly women's self-help group leaders, key male farmers, village elderly, enthusiasts, etc.

D. Detection of visible indicators

In addition, detailed surveys were conducted in each village that encompassed 90% of the beneficiary villages and respective households. The purpose was to identify and validate field practices (multiple cropping), household utilities (sustainable cooking gas or biogas, energy-efficient cooking ovens or smokeless *chulha*), water structure, micro-irrigation/lifting structures, weather stations, and forestry and assess their functional status. It was performed through observation, conversation with the stakeholders, demonstration by staff, small experimentation, and data (in the form of audio files, videos, or photographs) was recorded accordingly.

E. Data compilation and analysis:

Data in various formats (audio, video, photographs, and other formats from previous reports) are compiled and collated to obtain quantitive and qualitative information and insights.

Results:

The key findings related to the interventions:

1. *Hyperlocal Weather Stations*, serving an area of 10 sq.km., are functional in their areas. Agroadvisories are translated into a simple local language from the generated data, and sent out every five days. The community people confirmed that the forecasts are being sent to their respective mobile numbers while in the discussion. In addition, wall writing of the weather information is regularly updated (table - 1a). The role of agroadvisories in fine-tuning the decision-making process, e.g., time of sowing or transplanting rice, harvesting crops, irrigating, applying diluted cow urine in diseases, etc has

also become apparent. And not only averting loss or taking timely action, weather information also substantially reduced their drudgery and enabled effective utilization of labor (figure - 2a-c).

2. *Using Geoinformatics in water harvesting and micro-irrigation structures*: Employment of the cutting-edge technology with traditional ecological knowledge allowed better prediction for creating water structures that could continue holding more water than usual. Almost ninety percent or more of water structures are functional and noted to be performing well (figure - 3a-o) (table - 1b). A majority of ponds or *hapas* still retain the water of depth ranging from 2 to 14 ft, even in drier months like January and February when the field survey was conducted (figure - 3d-e,g-h,k-o). Almost all of the big ponds are serving their purpose, e.g., from irrigating rice crops to daily chores confirmed through FGDs and personal observation. It served dual purposes. On the one hand, they have been able to secure irrigation for paddy cultivation. On the other, it brought changes in cropping intensity, i.e, harvesting double and triple crops (Rabi crops) instead of a single crop (only rice).

3. *Drought-resilient farming and improving food and nutrition security*: Geoinformatics-informed rejuvenation or creation of new water structures enabled better and longer water availability for agriculture and non-agricultural purposes than the pre-intervention phase. Consequently, households that were carrying out only rice cultivation during the Kharif season are now harvesting another suite of crops during the Rabi season. Some were even exploring the option of growing the third crop (pre-rice). The FGDs followed by field visits also confirmed multiple cropping (rice, seasonal vegetables, leafy greens, oilseeds, spices, etc) as a widely adopted exercise to alleviate hunger and ensure food and nutritional security (figure - 4a-p)(table - 2). Weather stations and agro-advisory have lessened their misery and enhanced preparedness for precarious weather conditions. In addition, a small plot dedicated to homestead farming or nutrition gardens in the closest proximity to the households are generally replete with seasonal vegetables and offer copious supplies of additional food items at the time of need (figure - 5a-d). Previously, some of them were sporadically preparing kitchen gardens with one or two crops. But after the interventions, the practice gathered inertia, crop diversity rose dramatically with proper management. Now, most households have been growing at least nine to ten crops in their gardens to meet their nutritional need. Many of them have brought back and introduced several local vegetables or tubers in their garden.

4. *Social forestry and access to food, fuel, and fodder*: Small to medium forested landscape regenerated with multiple species of native trees such as *Senna siamea* (*Minjiri*), *Dalbegia sissoo* (*Sishu*), *Albizzia lebbeck* (*Sirish*), *Bassia latifolia* (*Mohua*), *Mangifera indica* (*Aam*), *Sygygium sp,* etc in selected villages to enhance water availability in the downstream region. After gaining maturity, they can also provide them with food, fuel, and fodder. Following the protection for the initial years, the forest patches are now growing and changing the face of the landscape (figure - 3j). The small patches of forests also facilitate the regrowth of sand-binding grass members and are thus expected to minimize soil erosion. Here as well, like pond digging or managing nutrition gardens, women took the lead role to spearhead this whole initiative. They negotiated with the land owners and were thoroughly involved in making legal arrangements, and led the entire process of developing social forestry.

5. *Traditional grain/seed banks*: Women SHG also pioneered the storage of rice in the traditional rice granaries or *dhaner morai* to store excess grain to be used in a lean season or in dire need. Interviews revealed that a few families were provided with rice from the banks when their earning members were

away from their homes during the surge of Covid-19 (figure - 6a-b). Besides, a few community seed banks were set up; where farmers store seeds of native crops, e.g., cereals, vegetables, pulses, and leafy greens. They were also found to be operative and regular updates of stock were conducted (figure - 6c-i). The culture of seed saving was also recorded and confirmed while surveying agricultural fields and households (figure - 6c, j-m). In other words, they were found to be saving or drying a small portion of crops for future use.

6. *Formation of WSHGs* and other purpose-driven groups: Women remained at the center stage of almost all interventions and they pioneered most of the enterprises, from social forestry to pond digging to kitchen gardens and traditional granaries. Throughout the evaluation study, social cohesion, strong bonding, and cooperation among the members of SHGs have been observed. Had it been not existing, offering labor from communities, erection of structures, and continuation of receiving services might have not been possible. The authors were also able to perceive and understand a sense of community ownership around the various assets, be it water structures, weather stations, forestry plots, rice banks, or *morai*. It also facilitated proper maintenance, record keeping, updation of savings earned through the selling of produce, mutual benefit sharing, and livelihood enhancement.

Discussion:

Low and erratic rainfall coupled with high temperatures in semi-arid regions are key constraints for smallholder farmers in India. The situation tends to worsen with the aggravated conditions, i.e., frequent spells of droughts. This water scarcity severely affects agricultural productivity, impairs food security, and income opportunities for farming households. The drought-prone regions of Puruliya and Bankura are no exception and are regularly battered by fluctuating weather. Hardships faced by women and girls are immense. On that note, the interventions have both short and long-term positive outcomes.

1. *Hyper-local Weather Forecast & Agro-Advisory:* In India, crop production has been hampered owing to moderate to severe drought or untimely and excess rain, delayed monsoon, higher temperature, and fluctuations in other weather parameters (Bhuiyan et al. 2006). Hyperlocal (covering a ten km radius) weather forecasting was anticipated to lessen this loss and proved more advantageous than district-level weather forecasts by the Indian Meteorological Department (IMD). Micro-weather data, translated into the local language, Bengali, accommodates these local variations and offers much-needed advisory to the surrounding villages in the forms of SMS, wall writings, and village meetings. Six stations in Kashipur (Kroshjuri, Nutandi, Ranjandih) and Chhatna block (Beriathol, Chachanpur, Jhunjhka) and several kiosks and groups were formed in the target villages for the efficient flow of information. This service has greatly enabled the stakeholders to be prepared and make informed decisions that led to a minimization of uncertainty in sowing, transplanting, harvesting of rice, irrigation planning, pest control, and selection of crops, their sowing, and harvest. FGDs also revealed the critical role of agro-advisories in reducing agricultural expenses and drudgery and averting crop loss. On the same note, Manjula et al. (2022) argue about seasonal climate forecasts in inducing risk-reducing decisions and building smallholder resilience. They enlisted a host of decisions, for example, time of sowing, irrigation management, resource use allocation, fertilizer applications, time of harvest, etc facilitated by

the local forecast. Similarly, Pulwarty and Sivakumar (2014) have also discussed the decisive role of various early warning information in drought risk management and adaptation.

2. *Improved Water Security*: water is the lifeline of any society, more is true for the communities living amidst water scarcity, vulnerability, and fluctuating weather regimes. Creating water structures of various scales and efficiency, ensuring availability, and enhancing equitable access to water for drinking, cooking, cattle feeding, washing and cleaning, bathing and irrigation thus remain crucial steps for any climate adaptation and building resilience in the areas under investigation. This remains a common response across geography. Chen et al. (2013) came across a host of strategies to enhance water availability closely linked to adaptation, e.g., investing in wells, maintaining channels, building cisterns, purchasing pumps, sprinklers, or pipes, etc. Along this line, the digging of *hapa* ponds, wells, or larger community-managed ponds seems to be indispensable. These structures still held a moderate to a good amount of water at the time of the visit suggesting better water availability. As a whole, the number of water bodies and total water area shot up significantly as a result of the initiatives implemented by DRCSC, local panchayats, and other government and non-governmental organizations (NGOs), in the last 5 years (Hazra et al. 2022). Survey responses have highlighted the fact that the new ponds, wells, and *hapas* were appropriately located in *Baid* and *Kanali* land as evidenced by their water availability in winter and later months. These initiatives have contributed to a significant reduction in drought risk in the villages. Furthermore, it also ensured community ownership around the developed water structures and generated employment opportunities (by offering paid manual labor) even in the pandemic situations when there was a severe shortage. It has been observed that local communities played a key role in participatory watershed development programs. The application of traditional knowledge combined with small-scale engineering or technological innovation aids in the development of watersheds and implement community-centric programs (Kumar et al. 2005). Also, raising awareness, sensitizing, and mobilizing the mass are integral to watershed development and sustainable management. Currently, many projects are operative in India, e.g., *Hariyali, Neeru-Meeru*, etc. *Hariyali*, a water-shed management project by the Central Government, attempts to empower the rural population to conserve water for drinking, irrigation, fisheries, and afforestation as well as generate employment opportunities.

   Watershed services extended by forest ecosystems are gaining recognition (Lele 2009). Planning, implementation, and development of community-protected and conserved forest patches with native trees headed by communities facilitated water availability in the downstream regions. Likewise, the project promoted the sustainable use of more than a hundred hectares of land and turned them into agroforests with multifunctional trees which can provide food, fodder, and fuel around the year. It guaranteed the long-term availability of water. Alongside, it restricted the planting of *Sonajhuri* (*Acacia auriculiformis*) and *Eucalyptus* trees for their well-known detrimental effect on local ecology and water availability. For example, *Eucalyptus* depletes groundwater, degrades soil fertility, and forms monodominant strands with no ground cover thereby intensifying erosion.
3. *Crop diversification*: One of the ways to ensure food security and sustainable livelihood option is to rely on a diverse set of crops depending on local agroecology. It not only insulates the cultivators of the risk associated with a single crop but also improves their access to diverse diets and nutrients derived from the mixed crops in the agricultural field (Mango et al. 2018; Pellegrini and Tasciotti 2014). In 2015 or

earlier, during pre-intervention days, they used to harvest only Kharif crop (rice) but that too was severely hampered had there been delayed, less or untimely rain. No provision of irrigation water (through micro-irrigation), absence of proper planning to conserve and judicious use of rainwater, and ill-maintenance of water structures kept them prone to hunger and pushed them to migrate and work as wage laborers. Ensuring water availability in agriculture is a foremost step that unleashed its benefits in many different ways. Apart from securing the production of primary cereal, the harvest of a second crop has been made possible. Seasonal crops like pulses, oilseeds, summer or winter vegetables, and a plethora of leafy greens have been grown in small plots in the same field in the Rabi or Pre-Khraif season (figure - 4,5; figure - S1a-e). A third crop, mostly summer vegetables or cucurbitaceous fruits fills up the gap in the pre-summer or late-winter period.

There were other management strategies that counted on proper crop selection that ranged from choosing early maturing or short life span crops to crops offering intermittent production throughout their growth cycle allowing small but regular financial support, and adjusting planting time/technique, etc. Employing various locally suited water-saving techniques of crop management also helped them to respond adaptively. Additionally, widespread acceptance and application of local resources, for example, cow dung, cow urine, ash, vermicompost, and biogas slurry as manure or disinfectant greatly helped them to save from ever-increasing agricultural expenditure. Simultaneously, it significantly lessened their dependence on market-bought agricultural inputs (figure - 7a-m). Put together, all these resurrected cultural practices appeared to render agriculture relatively resilient to external social, economic, or ecological shocks.

4. *Improved Nutrition Security & Health*: Like poverty, hunger and malnutrition are complex social problems that deserve a holistic and long-standing approach to alleviate. Often bottom-up interventions to find out the root cause, resolve the same with structural changes, and bolster the process to continue receiving benefits work efficiently. On the same token, the multiple complementary interventions by DRCSC like building of water structures to ensure agricultural water requirement, changes in agricultural practices to diversify crop packages and selection of drought-resilient crops, and provisioning of additional nutrition sources such as nutrition gardens, worked hand-in-hand to reduce hunger days, enable easier access to nutritious food, and improve dietary diversity. Setting up or revamping the nutrition gardens followed by judicious management of crop diversity was one of the very successful steps to bolstering nutrition status. In the neighboring state of Odisha, similar nutri-gardens tend to improve the dietary diversity of rural women (Niyogi 2020). Promotion and encouragement of the rearing of fish such as major carps like *Rohu* and *Catla* in the bigger ponds or the stocking of small *hapa*s with edible mollusks (*Gneri-gugli* in Bengali) allowed the stakeholders to reap the nutritious harvest. It has had a serious positive impact on the health and vitality of the community and was quite outwardly visible throughout the survey. Anthropogenic landscapes in rural areas are usually replete with uncultivated plant or animal food (Ray et al. 2020). This uncultivated diversity in the diet was also reflected in their inclusion of various seasonal forest produce, like mushrooms (mostly available during rainy seasons), wild fruits, tubers, and rodent meat. Alongside, a few carbohydrate-rich roots or tubers, yams, and taro (colloquially equated with *alu* or potato), often serve as a lean season crop, or drought food. These carbohydrate-rich tubers are generally large in size and have been promoted as effective strategic crops to be consumed during times of food

scarcity (figure - S1f,g). Hence, agricultural diversification along with the existing plurality in food cultures could contribute to diverse diets and may be an important strategy for the enhancement of nutrition outcomes (Jones 2017).

5. *Livelihood Diversification*: One of the ways to mitigate drought risk and instill climate resilience is through additional modes of income generation (Mohammed et al. 2021). Smallholder farmers often adopt a non-farm subsistence strategy to tide over an unfavorable period or generate income at the time of need. Stakeholders in the two districts were moderately successful in rearing livestock, sheep, goat, pig, and chicken (figure 8a-b). These allowed them to earn extra money by selling juveniles, young, or young adults. Low maintenance cost, since they can be fed mostly from household food excess, vegetable skin, culture *azolla*, decanted rice water, or raw or cooked food unsuitable for human consumption, has been proved to be economic (figure - S1h,i). Farming households across the world are often engaged in a plethora off-farm activities as an alternate livelihood strategy because it helps them to tide over unfavorable period and alleviate poverty. Many of them also depend on a dual mode of subsistence, crop production and animal husbandry (Woldehanna 2002). Thus, agriculture and livestock can be integrated in a way to be mutually sustaining.

   Future projection also underscores the potential of social forestry to generate income and enhance the livelihood of many. Currently, groups continue to receive support for fodder and fuel from the forest patches on a regular basis. After ten to fifteen years, as the forest trees mature these resources may create a huge forest-based income opportunity and support their livelihood.

6. *Reduced migration:* Ensuring livelihood in drought-prone districts is a challenging task that is the key step to reducing the seasonal migration of farming households to urban or peri-urban areas. Prior to 2015, males alone or accompanied by females and children used to travel to nearby cities, or town. According to a report in 2017, members from households with less than 3 bighas of land in Kashipur and Chhatna were the most likely to migrate seasonally. A survey revealed that 39%, 31%, and 30% of migrants earned as daily laborers, agricultural laborers, and livestock farmers, respectively (Hazra et al. 2022). It had supported their livelihood during the lean season. Rural migration is a common pattern worldwide and more so in developing nations (Viswanathan and Kumar 2015). This has been widely researched through the lens of economics, sociology, or other disciplines. Our study revealed multiple reasons underlying such phenomena, e.g., single crop in a year, low productivity owing to water scarcity, high cost of agricultural inputs, absence of other means of income generation, climatic vagaries, and uninformed about the proper method of agricultural practice. All of this compounded the problem of decent subsistence throughout the year and underlay the migration for an alternate livelihood.

   The complementary approach adopted in the project has enhanced water security, disseminated agro-advisory, taught methods of crop diversification, sustainable resource use, additional income generation, etc. It cumulatively acted to reduce hunger days (figure - 9), harvest crops other than rice, increase income and lessen market dependence. As a result, a general decline in migration has been noted that has been echoed in various formal and informal discussions (figure - 10). In research on Indian Sundarbans Delta, Hajra and Ghosh (2018) identified that out-migration is positively correlated with a decrease in agricultural productivity. The poor state of agriculture often turned out to be non-remunerative and non-farm incomes or remittances from cities emerged as a way out. In the

two districts, adaptive strategies ensuring water and agricultural development seems to be instrumental in the of decline in migration.

7. *Women's empowerment:* Many studies underscored how collective action can lead to environmental improvements that can manifest in income increment (Wu and Pretty 2003). On the same line, social connectedness nudges people to work together in a group and share the benefits of their common effort. Adger (2003) also illustrated a couple of examples of collective action for coping with extremes in weather in Southeast Asia and the Caribbean. These case studies also reinforced the nature of adaptation processes and the necessity of collective action in future climate changes.

Women take the center stage of any food provisioning activities of the households. Although men are known for their contribution to their larger share of labor in agrarian activities, women are no less active. A majority of tasks related to agrarian activities in the surveyed villages are performed by women. The formation of women SHG and their collective effort in most cases, e.g., digging or assisting in ponds, maintaining accounts, performing community works, etc provided inertia to kickstart and continue developmental activities. The authors have also observed non-quantifiable indicators while conducting this survey, e.g., strong social bonding and coopration among the group members, a sense of responsibility, mutual benefit sharing, a feeling of community ownership of water structures built at the village level, keenness to demonstrate their achievements such as agricultural produce, field teeming with crops, etc. Pertinently, Adger (2003) has also summarized that building trust and cooperation can be beneficial for any collective action. Synergistic social capital and inclusive decision-making institutions can promote the sustainability of any adaptation strategy.

Conclusion:

Summarising in light of the above data and interpretation, a few general aspects become apparent. The co-application of traditional ecological knowledge and geoinformatics, and the development of micro-irrigation structures warranted water provisioning. Weather data and agroadvisory enhanced the preparedness of the stakeholders and turned them into informed decision-makers. Both have a direct and positive impact on agricultural activities. A host of agricultural practices coupled with micro-irrigation facilities and agroadvisory made them reliant, less vulnerable, and food and nutrition secure (figure - 10). The entire system also appeared to score high on a sustainability scale. In other words, the use of cow dung or cow urine enabled local resource use or recycling, dependence on a suite of crops rather than a single turned them less risk prone, income diversification through livestock rearing, distancing from the market through seed saving initiative, souring farmyard manure, etc, all of which align with the spirit and indicators of sustainability. They are now better placed to tackle drought-related vulnerabilities, and the interventions have instilled resilience and empowered them to adapt to climate change (figure - S2).

Recommendations:

Although the complementary approach tacking the larger problem, well-planned interventions and their implementation, and the overall progress seem quite promising, a few measures can be suggested to take it further or converge with the existing interventions elsewhere.

1. Formulating and strengthening the operation of local village-level seed banks in a decentralized manner to bring the majority of stakeholders under its umbrella. In doing so, collection, documentation, characterization, and exchange of local agrobiodiversity could serve as facilitators in furthering the mission to reduce market dependence, at least for seeds - the key propagule of any farming enterprise. Extension services need to be catalyzed toward capacity building.
2. Complementing the above point, the exploration for drought-resistant or low resource-using landraces or heirloom seeds of local crops could be continued and attempts to be made to bring them back to a formal cultivation regime.
3. Introduction of water-thrifty cereals such as millets in ceratin agroecologies, especially in regions that were growing several millet species historically, prior to the Green Revolution era, could be continued. It could also follow a suite of coupled activities like harvesting, processing, and encouragement to consumption. It could converge with the Government of India's Millet mission.
4. Reducing the utilization of water (and perhaps methane emission) in rice cultivation through the direct seeded rice method instead of transplanted rice or rice paddies or wet rice. Historically, relatively arid regions counted on broadcast *aus* or autumn rice cultivation that consumed less water compared to *aman* or *boro*. A close inventorying can be performed to reintroduce heirloom seeds into the field. Besides, popularization and dissemination of relatively drought-tolerant heirloom varieties of rice (e.g., *Bhutmuri, Noichi, Kelas, Asanalaya*, *Radhatilak*, etc) or relatively higher-yielding (*Kerala Sundari*) can be espoused for their low resource use capacity and ability to withstand stress.
5. The widespread cultivation of cross-pollinating oilseed crops (mustard, sesame), vegetables (cabbage, tomato, onion, radish, carrot, various gourds, green chilies), legumes (*arhar,* beans), plantation crops (*Pongamia, Eucalyptus, Acacia, Syzygium*), *Moringa* open the door for integration of bee colonies in the field. It cannot only tap honey but can facilitate better fruiting through pollination service by bee colonies in the field achieving higher productivity - a win-win situation. The interventions can be brought under and merged with the 'sweet revolution' promoted by the Government of India.

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Table 1: Assets and their status of operations (functional / non-functional, water availability), a) weather stations and social forestry, b) micro-irrigation structures,

a) Weather stations and social forestry

Structures	Total	Visited (%)	Functional (%)	Comments
Weather stations	6	100	100	X
Social forestry	350 hectare	90	90	A few needs removal of unwanted invasive species

b) Micro-irrigation structures

Water structures/ Micro-irrigation/ Lifting structures	Total	Visited (%)	Functional (%)	Water availability (January-February 2023)
Hapa (small pond)	1225	70	95	2-8 ft
New pond	40	80	90	0-14 ft
River lift irrigation	4	100	100	Available
Check dams	4	60	90	Available
Solar-pump assisted lifting	7	80	100	8-14 ft

Table - 2: Crop diversification and intensification: a. nutrition garden b. mutli-cropping c. strategic crops/lean-season crops, d. seasonal delicacies

	Adoption by households	Functional / in practice	Kharif	Rabi
Nutrition Garden	85%	80%	Leafy greens, Summer vegetables	leafy greens, winter vegetables, spices

Mixed cropping or multi-cropping	95%	90%	Primarily rice, leafy greens, seasonal cucurbitaceous vegetables, summer fruits	leafy greens, species, winter vegetables, oilseeds, pulses
Strategic /lean-season crops	Many of them brought back these crop into their homestead or around		Various non-potato carbohydrate-rich roots and tubers, e.g., yams, arum, taro, etc for consumption during hunger days	
Seasonal delicacies (e.g., mushroom)	Nearly all collect mushroom in the season		Various mushroom species collected from the nearby forest during rainy season	

Figure -1a-d: Field visits and FGD; Figure 2a-b: Hyperlocal Weather Station and a wall display of agro-advisory; Figure 3: a-b. solar-assisted irrigation, c. Check dam, d-e. Step ponds, f. *Arhar* or *Cajanus cajan* cultivation on the embankments

Figure 3: g-h. Step ponds, i. Gourd cultivation on the embankments, j. Social forestry patch, k-o. *Hapa* ponds and their water level during the assessment (January-February 2023); Figure 4: a-f: Diverse agricultural practices

Figure 4: g-l. Diverse agricultural practices, m-p: agricultural produce of the Rabi season; Figure 5: a-d. Kitchen gardens teeming with various crops

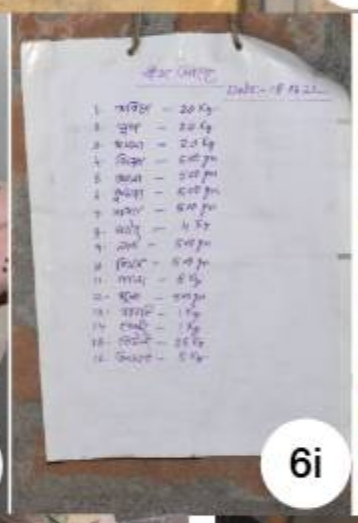

Figure 6: a-b. Rice bank; c-m: seed saving initiatives, community seeds banks, raising and drying crops for seed collection

Figure 7: a-m. Smoke-less oven, Biogas, slurry and vermi-compost pit, cow urine collection, and cow dung collection, ash application in the onion field; Figure 8: livestock rearing

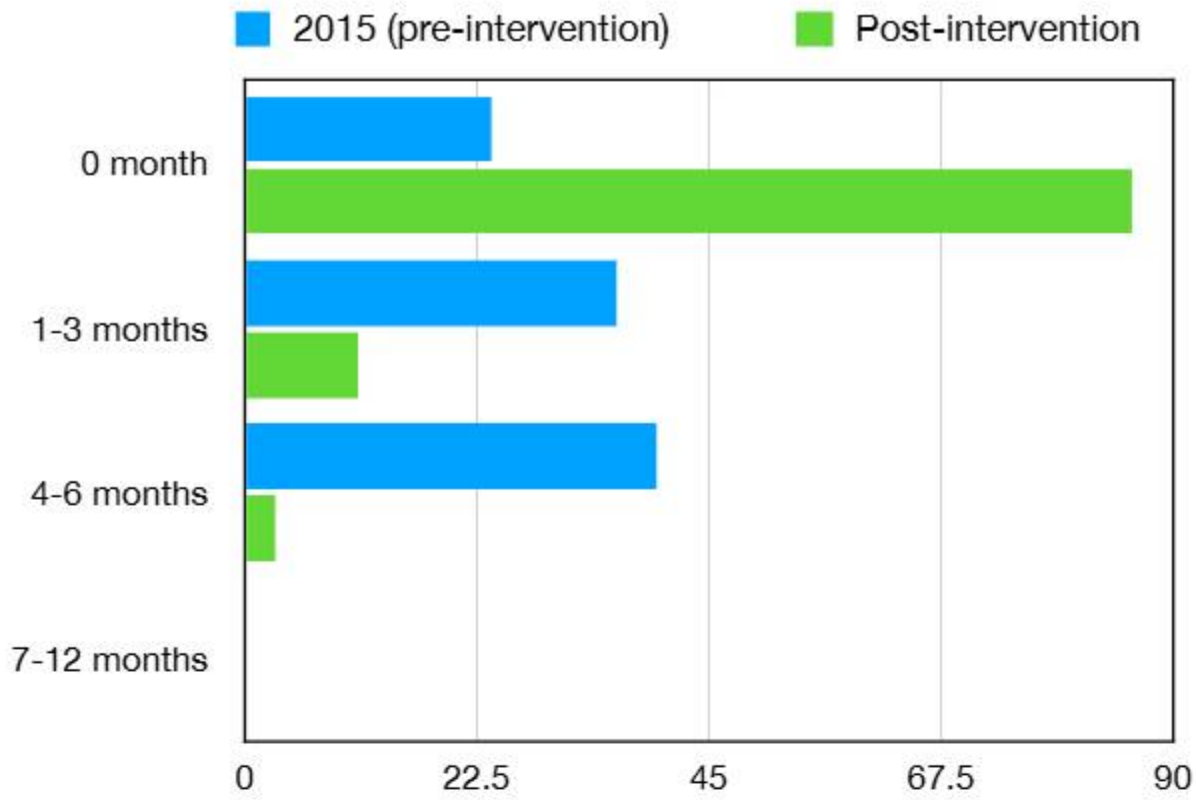

Figure - 9: Percentages of households experiencing hunger days between 0 and 12 months in 2015 and in 2021 (from Hazra et al 2022)

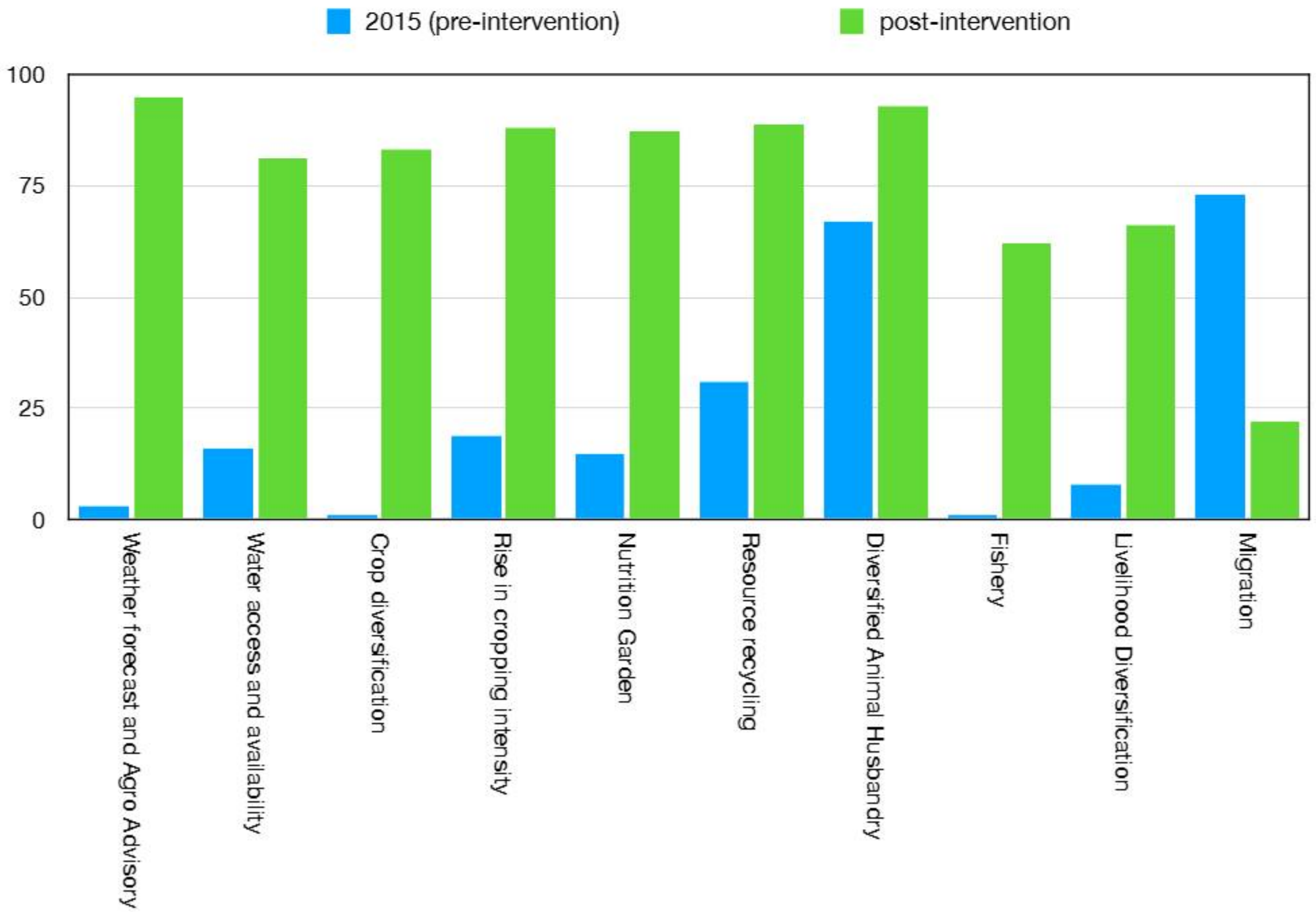

Figure - 10: The benefits of interventions received by households (%) as a comparison between 2015 (pre-intervention) and post-intervention phase.

Annexe

Figure S1: Views from the villages a-e. Crop husbandry; f-g. Uncultivated edible; h-i. bioresource - *Azolla*

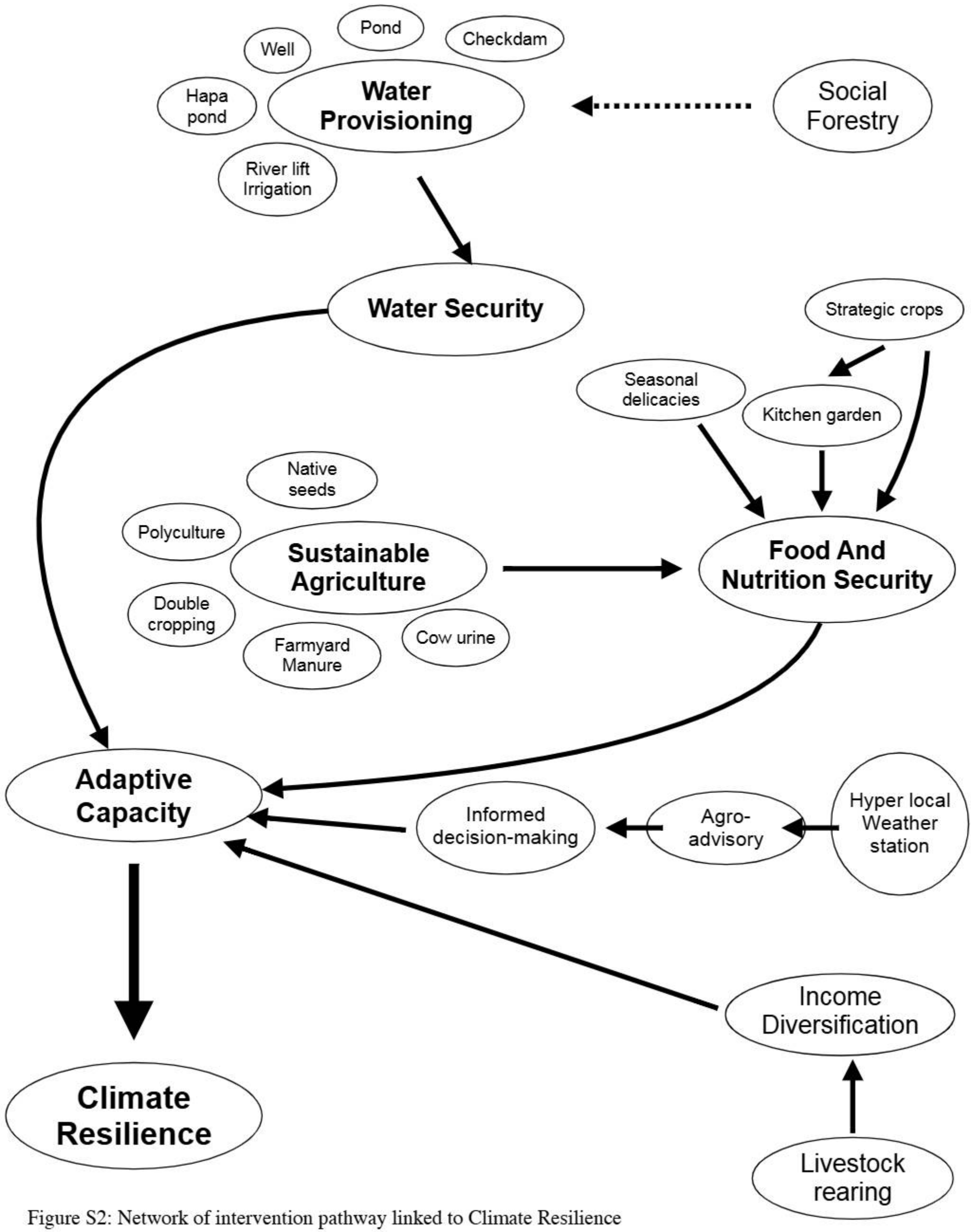

Figure S2: Network of intervention pathway linked to Climate Resilience