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RESILIENCE INTEL

Fostering Inclusive and Sustainable Agricultural Value Chains: The role of climate-resilient infrastructure for SMEs

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Key messages:

- Investments in climate-resilient infrastructure, particularly if smaller scale, need to consider the local context, especially the physical and human resources available. This requires integrating technical considerations with participatory approaches, and also ensuring equitable access to resilient infrastructure.
- It is important to ensure the buy-in of local stakeholders and to invest in capacity-building support for local institutions managing the infrastructure, as this can significantly contribute to the sustainable management of assets. Considering the role of investment-support facilities targeted to agri-businesses to access credit for integrating climate-smart features in construction is also crucial, especially when issues linked to financial literacy and client protection are taken into account.
- Proper integration of climate change in the planning and maintenance of infrastructure at different levels should be consistent with countries' national and local priorities and be supported by regional and community plans. At national level, climate considerations should be introduced into the regulations and incentive systems of infrastructure sectors and value chains –for example by incorporating climate-resilience design specifications into the national Building Code.

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1. Introduction

With the impacts of climate change already being felt, stepping up climate adaptation efforts is becoming crucial for the global development agenda. For this reason, the UK (co-)led the track on resilience at the recent UN Secretary-General's Climate Action Summit of 2019. In raising ambition for climate adaptation, the UK commitment is focusing on selected pillars. One of these relates to resilient investments to embed risk in decision-making across the public and private sectors.[1] This covers issues such as climate-resilient infrastructure investments, land use and risk financing in value chains.

Two multi-country programmes, mainly funded by the UK's Department for International Development (DFID), exemplify this commitment to help economies and societies cope with the impacts of climate change and build more resilient livelihoods: the Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED, implemented across 13 countries) and the Adaptation for Smallholder Agriculture Programme (ASAP, with operations covering 41 countries). The similarities between BRACED and ASAP are multiple, and different areas of common interest have been identified. These include the use of value chain approaches to identify and support different actors along the chain, from smallholders to processors, traders and service providers, as well as the role played by infrastructure. These issues are also crucial for the attainment of the 2030 Agenda for Sustainable Development, in particular for Sustainable Development Goal (SDG) 9, which aims to build resilient infrastructure, integrate small-scale enterprises into markets and value chains and promote sustainable economic transformation.

The aim of this study is to draw on BRACED and ASAP examples and, more broadly, review evidence on initiatives investing in climate-resilient infrastructure to support smallholder farmer organisations and agri-businesses in the micro, small and medium enterprises (MSMEs) category and, ultimately, foster inclusive and sustainable agricultural value chains. The study will provide an overview of the literature to examine whether initiatives aimed at supporting resilient infrastructure, particularly small-scale infrastructure, have the potential to favour an increase in smallholder participation in value chains. In order to inform operational practices and institutional policies, we also present a series of short case studies of BRACED and ASAP examples, based on comprehensive reviews of programme-related documents and relevant background reports.

This study proceeds as follows. Section 2 reviews the evidence on the role of climate-resilient infrastructure in supporting MSMEs. Section 3 presents brief examples based on BRACED and ASAP experiences. Section 4 concludes and offers recommendations for policy and programming.

1 https://www.un.org/sustainabledevelopment/wp-content/uploads/2019/05/WP-on-Resilience-Adaptation.pdf

2. Climate-resilient infrastructure for agri-businesses

2.1 Background and definitions

Infrastructure is essential for participation in value chains to upgrade economic structures. It can power farms and businesses, improve market access, connect workers to jobs and – if well allocated – help in reducing inequalities. It can lower production and transaction costs, increase the efficiency of services, support the diffusion of innovative technologies, 'crowd in' other productive inputs such as foreign direct investments, better link product and factor markets and ultimately foster inter-regional trade. In addition, supporting the necessary complementary institutions and regulations, or so-called 'soft infrastructure', can address market failures in the value chain and assist in processes of economic transformation.

Investments in hard and soft infrastructure can indeed help in promoting horizontal coordination and diversification, as well as vertical interactions and integration between segments of value chains (Engel et al., 2015). Hard (tangible) infrastructure often refers to the transport system (e.g. roads, livestock corridors), public utilities (e.g. water supply and sewer systems, irrigation, energy and farm power systems), green infrastructure (e.g. trees, perma-garden structures), other small-scale physical infrastructure (e.g. storage facilities, processing facilities and equipment, cold infrastructure for preservation) and communication networks. Soft infrastructure refers to matters related to efficiency, such as institutions and regulations. Advisory services to channel climate information to smallholders are a good example.

Also, investments in infrastructure are fundamental to sustain growth. In 2010, the World Bank's Africa Infrastructure Country Diagnostics showed that infrastructure funding gaps were substantial. As an example, in irrigation, Africa's infrastructure funding gap was estimated to be $4.9 billion a year – second only to the power sector (Foster and Briceño-Garmendia, 2010). In response, the Programme for Infrastructure Development in Africa, endorsed in 2012 by the continent's heads of state and government, lays out an ambitious long-term plan for closing Africa's infrastructure gap (Cervigni et al., 2015).

Unfortunately, the problems with Africa's infrastructure and business environment are well documented, and they affect MSMEs disproportionately. Surveys among small businesses identify poor infrastructure services, particularly electricity supply, as a relevant bottleneck, as important as insufficient access to finance (Page and Söderbom, 2015). This study focuses on infrastructure suitable for MSMEs – that is, small-scale infrastructure projects such as those the ASAP and BRACED programmes support. Illustrative examples of these include the following:

- transport: access roads and feeder roads
- water: family- and group- owned and -managed irrigation schemes, soil and water conservation systems, roof-water harvesting tools
- facilities: market structures, collection centres, pack-houses and cold storage units
- processing: equipment to process agricultural products, with climate-smart locations and powered by renewable energy
- energy: local connectivity for agriculture (e.g. irrigation pumps) and energy production for agricultural facilities (e.g. biogas).

Given the nature of infrastructure, with high initial sunk costs and long service life (of one to two decades for small-scale infrastructure), there is a clear need to redesign and overhaul it to withstand the strain of recurrent droughts, floods, wind storms, warming temperatures, heat waves and changing climates. Examples of climate-resilient and -smart infrastructure solutions based on climate risk considerations and analyses comprise the following:

- transport: improved drainage, alternative construction material (e.g. reinforced concrete), modified designs to raise structures, submersible roads, improved bridges, slope protection
- water: drip or micro-jet irrigation, lining of canals, changes to flow velocity, new building codes for dams and canals
- facilities: modified designs, siting and construction materials, deeper foundations, protective walls, vegetated contour bunding
- energy: solar pumps, biogas digesters, plants with reduced water needs, solar cooling.

2.2 The relevance of investing in climate-resilient infrastructure

A recent World Bank report on climate-resilient infrastructure estimates that infrastructure disruptions impose costs of up to $647 billion a year on individuals and businesses in developing countries (Hallegatte et al., 2019). There are various reasons for such disruptions, such as poor maintenance, mismanagement and underfunding, but case studies suggest that natural hazards explain 10–70% of them, depending on the country context, and show that often people who do not experience direct damage from disasters still suffer negative impacts from infrastructure disruptions (ibid.). The same is true for firms: disruptions can leave production capacity unused, reduce sales and delay the supply of inputs and the delivery of goods, on top of generating expenses for coping with unreliable infrastructure.

Costs arise not only as a result of disasters linked to natural hazards: increased climate variability can create disturbances too. For instance, failure to integrate climate change into the planning of water infrastructure could entail, in the driest climate scenarios, significant yield losses and, in the wettest scenarios, foregone revenues, if the larger volume of precipitation is not used productively. Moreover, infrastructure can influence adaptive behaviours – shifts in weather patterns may result in shifts in crop production and trade patterns – but the capacity to utilise trade in response to climate change depends on the availability of appropriate infrastructure – for example of suitable transportation and processing facilities.

Hence, investing in more resilient infrastructure is urgent and profitable. Focusing on low- and middle-income countries, Hallegatte et al. (2019) estimate that, while designs for more resilient assets would involve an incremental cost of around 3% compared with total investment needs, for each $1 invested the net benefit amounts to $4 in a median scenario. Also, on average, climate change doubles the net benefits from investing in resilience, whereas making infrastructure users better able to manage disruptions can reduce the costs.

Such investments can help avoid losses when disasters strike, stimulate economic activity through reduced risks and develop co-benefits, as the benefits of climate-resilient infrastructure can be interpreted in terms of the 'triple dividend of resilience' (Tanner et al., 2015; Hewitt, 2017), including:

- Avoided losses: More robust infrastructure can reduce or avoid costly repairs and minimise downtime and economic disruptions in the event of a disaster. This reduces the life-cycle cost of the asset.
- Economic potential: More reliable infrastructure networks and services can result in enhanced market access, or better protective infrastructure can increase land values, such as climate-smart irrigation schemes.
- Development co-benefits: Green contour bunding and other solutions based on trees and forestry can provide ecosystem services such as water conservation and reduced use of forests for firewood.

2.3 Understanding the role of climate-resilient infrastructure for agri-businesses

While a number of multilateral development banks, donors and development finance institutions have developed methodologies to take climate into account in their infrastructure investment strategies, it is important to review these approaches and illustrate how they can be applied across a range of conditions.

A body of good practices has begun to emerge as various international institutions have started mainstreaming climate issues into policy-making processes and investment decisions. For instance, Caron et al. (2018) shows how, in Southeast Asia, after a period of focus on building large-scale irrigation infrastructure serving production growth, there appears to be increasing interest in supporting irrigation projects that serve climate change adaptation priorities. These include strengthening the management of small and medium irrigation structures, adjusting irrigation practices in response to transformations in production, protecting landscapes and conserving water resources, improving water use efficiency, investing in infrastructures for flood control and drainage and implementing Payment for Ecosystem Services schemes to regenerate water resources in the upstream watersheds.

Indeed, climate-resilient infrastructure must enable communities, households and MSMEs to adapt to climate change impacts. To date, discussions on climate-resilient infrastructure have often focused on addressing the resilience of critical national infrastructure, potentially to the neglect (or detriment) of local community resilience. As an illustrative example, resilience-building maintenance work on roads, such as improving drainage and enhancing surface run-off, thus discharging into the surrounding areas, may carry pollutants onto agricultural land and into groundwater sources. Hence, according to Gallego-Lopez and Essex (2016), there is a need to increase community involvement in infrastructure design and monitoring, including information-sharing sessions and possibly consultations with both groups of men and women (as their views can be different, e.g. women and men often do not crop the same commodities and do not use frequent the same places). Another way to involve communities is to make them real actors in local development processes. For example, the International Fund for Agricultural Development (IFAD) fosters processes led by local governments willing to mainstream climate change in medium-term planning in a range of vulnerable countries, such as Mali and Viet Nam. Also important is to design relevant environmental and social safeguards, even in the case of climate-smart infrastructure.

In shedding light on the role of climate-resilient infrastructure for household welfare and MSMEs, it is important to better understand what mechanisms can explain the impacts on beneficiaries and target communities of increasing the robustness of infrastructure. A growing literature explores this topic.

For instance, there is an emerging strand of evidence on the effects of small-scale transport infrastructure on rural development. Gonzalez-Navarro and Quintana-Domeque (2016) illustrate that street asphalting of peri-urban roads significantly increases property wealth. Stifel et al. (2016) estimate that rural feeder roads in Ethiopia have relatively high internal rates of return, even in less favourable settings, where, for example, motorised transport services are not guaranteed. Asher et al. (2018) compare the environmental effects of constructing feeder roads and upgrading national highways to show that, while new rural roads have zero effects on local deforestation, highway upgrades cause substantial forest loss. Asher and Novosad (2018) also highlight that feeder roads allow workers to get extra nonfarm work outside of the village. Similarly, Brooks and Donovan (2019) measure the impact of building bridges in rural areas where seasonal flash floods cause frequent transport disruptions and find that bridges significantly reduce the risk of losing labour market income during floods, as well as increasing labour market incomes in non-flood periods. The authors describe how these effects unlock resources for investment previously held to mitigate consumption risks. As a result, farmers spend 60% more on intermediate inputs and farm profits grow by 75%, while household welfare increases by 28% –making the construction of climate-resilient transport infrastructure a cost-effective solution.

In line with these results, Yaron et al. (2017) review a series of BRACED case studies and assess that, over a 10-year window, the economic benefits of BRACED community interventions are significantly greater than the estimated costs. The highest returns are from small-scale infrastructure investments, such as rainwater harvesting and storage facilities, which draw on BRACED finance and community contributions of labour and are planned jointly with communities (and local governments) considering their climate resilience priorities.

2.4 Increasing MSMEs' participation in agricultural value chains through infrastructure

Given the importance of infrastructure for the functioning of value chains, there is also a need to better understand the link between climate-resilient infrastructure and resilient value chains. Using different value chain approaches, several recent studies show that the disruptive impacts of climate extremes and disasters on infrastructure can spread far beyond directly affected firms – especially as they become more specialised and interdependent (Baldwin and Lopez-Gonzalez, 2015) – and ultimately generate systemic risks (Colon et al., 2017, 2019).

For example, through reduced connectivity and input shortages, more firms suffer losses in production and sales (Hallegatte et al., 2019). This results in lower investments because of the lower profitability of affected firms, reductions in workers' incomes and a drop in the demand up the value chain. Also, Colon et al. (2019) find that, in Tanzania, the macroeconomic impact of a flood disruption in the transport sector increases nonlinearly with the duration of the disruption; Reardon and Zilberman (2018) show that the robustness of irrigation, drainage and flood control infrastructure upstream in the supply area is a crucial mitigating factor of the impact of flooding (and drought) shocks on the value chain.

Arslan et al. (2019) and the broader literature on the topic highlight how important it is for rural development to prioritise investments in climate-resilient infrastructure that can enhance community-level resilience and foster smallholder participation in value chains through better and more reliable access to markets (see Box 1).

Box 1: How investing in climate-resilient infrastructure can improve agricultural value chains and participation of smallholders

Going a step further, Arslan et al. (2019) explore how climate-resilient infrastructure can improve both the sustainability and the inclusiveness of agricultural value chains by increasing the participation of smallholders. The authors assess the impacts of IFAD's support in Bangladesh focusing on the effects of the Coastal Climate Resilient Infrastructure Project (CCRIP), which aims to improve the connectivity of agri-businesses in the face of climatic shocks (see Figure 1: Climate Resilient Infrastructure Project Theory of Change, for further information on the Theory of Change of the project).

The main component of the project is the construction of improved community markets and market connecting roads that are designed to remain useable during the monsoon season through tailored climate-resilient design features (covering various dimensions such as height, siting and construction materials) and the distribution of a 'check list for compliance of climate resilience' among contractors to ensure they are aware of and can be held responsible to meet the set standards.

Arslan et al. (2019) find that the project increased agricultural sales and, in particular, the amount sold at a market rather than from home or the farm gate. While before the project farmers had often been forced into taking lower prices by selling to traders directly after harvest at the farm gate, the recent availability of favourable marketing options and the better connection to storage facilities had changed the situation. Results also comprised increases in the likelihood of growing cash crops, higher on-farm incomes and incomes from wage labour, which together had increased total household income by 11%. Larger impacts on income had been achieved for the poorer, more remote households.

Among the lessons to be learned, the authors highlight the importance of ensuring the buy-in of local stakeholders and the availability of land. For instance, as a result of the limited availability of land, CCRIP had to focus on the retail function of markets and missed out on developing a wholesale function. Also, positive impacts were facilitated through capacity-building support to the local institutions managing the markets, which contributed to their sustainable management. CCRIP facilitated Market Management Committees, made up of local government and market users (with a quota for women) who were tasked with administration, maintenance and security of markets. Local government was in charge of enforcing the legal stipulation that 25% of the market lease income should go on maintenance costs.

Figure 1: Climate Resilient Infrastructure Project Theory of Change

INPUTS AND ACTIVITIES

Roads

- Build and upgrade climate resilient roads, bridges and culverts

Markets

- Build/improve climate resilient physical markets and their facilities
- Restructure financial management of markets and build capacity of Market Management Committees
- Provide information on farming practices, prices, and weather through radio service

Women

- Form and train Labour Contracting Societies (LCS) on construction and other income generating activities
- Contract LCS members to conduct road and market construction works

Climate change adaptation

- Build/improve cyclone shelters, upgrade access tracks
- Build community disaster preparedness cap. building

OUTPUTS

- Improved household connectivity: schools, hospitals, financial services, support services, etc.
- Improved farm connectivity: input and output suppliers and markets, technology/ facilities, other ag. services such as livestock vaccination
- Better managed, more vibrant markets with more buyers and sellers
- Sustainably structured market management and lease payment systems
- More climate resilient road and market infrastructure
- Increased employment and income generating capacity of women
- Improved capacity to rehabilitate infrastructure after shocks
- Improved access to climatic shock protection

OUTCOMES

- Higher education enrollment rates, reduced illness, better social security, etc.
- Higher crop productivity and quality from improved input and financial service access
- More diverse crop production from improved input and financial service access
- Higher volume of goods sold and profits from sale from higher productivity and crop quality, reduced transport costs, value chain inclusion and better prices from better-functioning markets
- Livelihoods less affected by climate stresses and shocks
- Diversified household income from improved income generating capacity of women
- Increased bargaining power of women due to improved income generating capacity

IMPACTS

- Increased sustainably and smoothed income
- Increased stability and resilience of livelihoods
- Increased household and productive asset ownership
- Increased food security
- Empowerment of women

ASSUMPTIONS - Factors that need to be in place for the outputs, outcomes and impacts to be achieved

- There is sufficient demand and institutional support for the activities
- There are no issues with acquiring land or other materials for the work
- Women are willing and able to work in LCS

- Roads, markets and shelters are well placed and well-designed
- Training for LCS is suitable

- Farmers face no other barriers to their productivity or their market participation – lack of labour, lack of capital etc.
- Income generating capacity is the only barrier to women's empowerment, they face no other barriers.

Source: Arslan et al. (2019), Figure 1 on page 11

3. ASAP and BRACED approaches in sub-Saharan Africa

This section presents a series of brief case studies on the role of climate-resilient and -smart infrastructure in reducing vulnerability and increasing adaptive capacities for MSMEs and market-active households along relevant agricultural value chains across sub-Saharan Africa (SSA), with examples from both East and West Africa. In the process of selecting relevant case studies, we followed the guidelines outlined in the IFAD (2015) manual on the elements to consider in assessing climate risks along value chains. Also, given our interest in exploring issues related to the performance of small-scale infrastructure, we selected case studies where either the projects had already been completed (under BRACED) or had gone through a mid-term review (under ASAP).

3.1 Approaches in East Africa: climate-resilient infrastructure for food processing and trading

Along agricultural value chains, there is a need to ensure that climate risks are managed not just at the production level but also throughout the rest of the value chain, especially at the process level. Both farmers and processors tend to be more vulnerable to climate hazards than middlemen, owing to their limited diversification, weak organisational capacities in some countries and often-unfavourable policy environment. Across SSA, most smallholders are already making some efforts to minimise the negative impacts of climate hazards on their activities, but not all responses are sustainable and initiatives to further support these private efforts are needed (Crick et al., 2018).

In East Africa, as population and urbanisation rates increase, the demand for food is rapidly rising and the food sector holds huge potential for growth: by 2040, it is anticipated that the value of food purchased in the region will grow seven-fold (Tschirley et al., 2015). However, local small-scale food processors and traders have difficulties producing products that meet standards, owing to limited business skills, lack of appropriate investments and often-unreliable infrastructure.[2] While large losses are characteristic of harvesting and post-harvest handling of agricultural products by smallholders in all low-income countries, there is a significant risk that losses will be exacerbated in countries more vulnerable to climate change as fluctuations in temperature and humidity can significantly increase spoilage of stored commodities and result in nutrient and quality losses. A recent meta-analysis reviews previous evidence on post-harvest losses in SSA and finds that losses range from 4% to 21% (Affognon et al., 2015).

Hence, this section focuses on the role of climate-resilient and -smart post-harvest infrastructure. This relates to siting and

2 https://www.technoserve.org/files/downloads/solutions-for-african-food-enterprises-final-report.pdf

construction materials of storage and processing facilities, use of energy and water infrastructure in post-harvest management, transport hubs and routes, refrigeration processes and cold chains. This is importance since, with shifts in the timings of the cropping seasons, harvesting now can take place at wetter times of the year, and smallholders can no longer rely on the sun to dry their harvest to safe moisture content levels for storage. Similarly, in dairy value chains, water scarcity influences fodder production, while heat waves complicate the transport, cooling and safe storage of milk in the value chain.

3.1.1 ASAP in Rwanda

Rwanda ranks 114th out of 181 countries on the resilience ND-GAIN index (2017). Specifically, it ranks 153th on vulnerability and 94th on readiness – meaning it is highly vulnerable to climate change effects but its readiness to combat these effects is moderate.[3] Climate projections for the country include 1.4–2.3°C increases in temperatures by 2050 and increases in the duration of dry spells and heat waves, as well as in the frequency and intensity of heavy rainfall (2019).[4] In the agriculture sector, this will increase the risk of pests and diseases in crops and of damage to crops and agricultural infrastructure.

In Rwanda, according to Bendito and Twomlow (2015), estimated post-harvest losses can be as high as 30%, since almost all rural post-harvest and storage infrastructure does not comply with basic guidelines for climate resilience. Hence, the National Adaptation Programme of Action and the 2011 National Strategy on Climate Change and Low-Carbon Development highlighted improved post-harvest management as a key climate change adaptation priority.[5] IFAD launched ASAP in 2012 and Rwanda was an early beneficiary of ASAP investments, receiving $7 million in 2014 to support the Climate-Resilient Post-Harvest and Agribusiness Support Project (PASP), which was designed to fill such a gap.

The main component of PASP aims to increase climate resilience and support post-harvest agri-business investments through the provision of co-funding for climate-smart infrastructure development as well as the promotion of climate-smart post-harvest equipment and materials, such as solar drying tunnels and biogas-fuelled grain driers.[6]

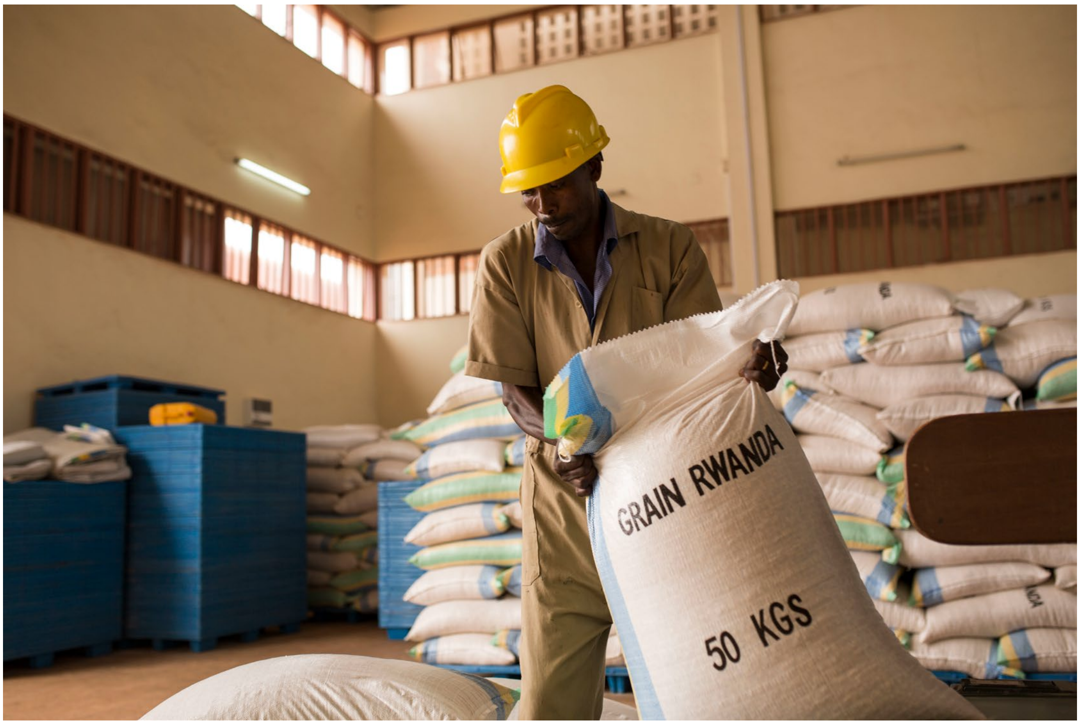
More specifically, interventions include capacity development among farmers' organisations to access funding from commercial lending for integrating climate-smart features into warehouse construction and other post-harvest infrastructure, such as in better rainwater management structures and roof designs modified to be wind-proof.

3 On the ND-GAIN index, vulnerability measures the exposure, sensitivity and ability to cope with climate-related hazards by accounting for the overall status of food, water, environment, health, ecosystem services, human habitats and infrastructure within a country. Readiness targets those portions of the economy, governance and society that affect the speed and efficiency of adaptation. https://gain.nd.edu/our-work/country-index/rankings/

4 https://www.climatelinks.org/sites/default/files/asset/document/2019_USAID-ATLAS-Rwanda-Climate-Risk-Profile.pdf

5 https://www.ifad.org/en/web/knowledge/publication/asset/39573019

6 https://www.ifad.org/en/web/operations/project/id/1100001497/country/rwanda



IFAD/Christopher Neglia

PASP has implemented an investment support facility for agri-businesses to access 'small' loans up to $40,000, 'medium' up to $100,000 and 'large' up to $200,000. PASP grants cover between 30% and 40% of the borrowed amount depending on whether the business is existing or a start-up and on whether the climate risk reduction classification is moderate or notable. The borrowing farmer organisations pay the balance to the lending financial institution.

Moreover, demonstration infrastructures are constructed by means of a funding arrangement between the programme, local government structures and farmers' organisations, under which PASP provides 40% of the cost, the government 40% and farmers' cooperatives 20% – mainly through in-kind contributions, such as building plots and labour during construction. Pilot demonstrations comprised a dozen climate-resilient warehouses and drying hangars in the drought-prone Eastern province, constructed according to standardised climate-resilient guidelines.[7] The infrastructure also included solar panels for lighting and rainwater harvesting installations for drinking, basic crop processing and cleaning. In parallel, a policy component worked on the creation and diffusion of appropriate guidance and building codes for the construction of climate-resilient post-harvest structures, as well as on capacity-building of relevant government staff and local contractors to design and construct safer structures.

7 Standardised features included structure height, width, slope and pitch of the roof, distance between each column and roofing truss, width of roof overhang, thickness of floor slab and rainwater management systems. Use of metallic materials, burnt bricks and concrete were preferred to eliminate the wood-eating termite risk. Functional considerations for storage also included suggestions for cyclophane turbines and so-called N-vents for internal humidity control. Considerations on the location comprised taking into account flood risk, contaminant seepage and industrial sources of pollution.

As a result, the design specifications for climate-resilient warehouses have been incorporated in the Rwanda Building Code as a national standard.[8]

In 2017, Rugege and Vermeulen (2017) collected data on farmer perspectives on the infrastructure built and on the promotion of the post-harvest materials distributed. At the time of the assessment, a 'small' grant had been disbursed to a maize cooperative to construct a warehouse, and a 'large' grant to Pasta Rwanda to build a maize processing unit with climate-smart aspects including biogas digesters, solar power and rainwater storage tanks. Cooperative committee members expressed appreciation for the intervention, mentioning among the benefits reduction of post-harvest losses in maize and beans, having space for offices and meeting rooms, lighting and power for electronic equipment from the solar installations and water from rainwater harvesting. Regarding the pilot warehouses, some cooperative leaders seemed to grasp the promotion approach and were looking to PASP to facilitate affordable supplies of the necessary materials. Other cooperative leaders indicated that they had felt left out of the processes of conceptualisation, planning and implementation of infrastructure: they had been expecting to oversee all related activities, including construction. Given donor and public procurement requirements, construction of the infrastructure was carried out through a tender process among third-party contractors, during which the cooperative members felt a lack of control. This suggests that, in supporting the development and scale-up of climate-resilient infrastructure, there is still a need to better understand how to balance and integrate technical requirements with participatory approaches.

3.1.2 BRACED in Kenya

Kenya ranks 150th out of 181 countries on the ND-GAIN index (2017). It ranks 149th on vulnerability and 152th on readiness, showing very poor readiness and high vulnerability. Climate projections for the country include 1.2–2.2°C increases in temperatures by 2050 and increases in the severity of dry spells and in the duration of heat waves, as well as in frequency and intensity of heavy rainfall – along with 16–42 cm rises in sea levels (2018).[9] In the agriculture sector, this can lead to reduced rates of reproduction, growth and milk production for livestock and to degraded crop and pasture land.

Arid and semi-arid Lands (ASALs) make up more than 80% of the country's land mass and almost 50% of animal production, while nearly 98% of crop production is rain-fed.[10] This means that food security remains a major challenge in Kenya, with deep-rooted underlying causes, including chronic poverty, high population growth, dysfunctional markets, limited investments in ASALs and poor infrastructure (Jobbins et al., 2018). Climate change exacerbates this situation. The BRACED programme working in the ASAL region of north-eastern Kenya is known as PROGRESS. It

8 https://www.ifad.org/en/web/operations/project/id/1100001497/country/rwanda
9 https://www.climatelinks.org/sites/default/files/asset/document/2018_USAID-ATLAS-Project_Climate-Risk-Profile-Kenya.pdf
10 https://www.ifad.org/en/web/knowledge/publication/asset/39572753

is implemented by Mercy Corps to build the adaptive capacities of households in the face of increasing climate risks.

In Wajir county in the north-east, targeted by the project, climate-related risks include drought, increased aridity, flash floods, soil erosion and bushfires. All of these contribute to environmental degradation, which reduces the local resource base for viable livelihoods. Hence, a main component of PROGRESS aims at market systems development with a focus on livestock markets, climate-smart agriculture and clean energy products, and it emphasises linking women with market actors in value chains and financial services.

Under this component, Mercy Corps launched a pilot activity to upgrade supply corridors for camel milk in Wajir county. Camel milk and meat are an essential part of the local diet, with camel milk contributing 50–60% of the nutrient intake of some pastoralist communities, especially during the dry season. Camel milk sales can also contribute significantly to household incomes throughout the year (Elhadi et al., 2015). Moreover, camels are able to thrive in arid environments, as they require less water and have less invasive grazing practices compared with other livestock.

According to a local market assessment, an estimated $68.2 million of camel milk is produced annually in Wajir county, with only 5% marketed commercially (Gitonga, 2017). At the same time, Mercy Corps' 'willingness to pay' study found that people would be willing to pay 20% more for fresh camel milk. Despite this potential, the camel milk value chain remained underdeveloped. Limited road networks, long distances between rural and end markets, incomplete linkages among market actors and poor storage of milk substantially impeded growth. The main challenges were found at the primary trader level, including absence of cooling facilities, use of plastic containers for transport and lack of dedicated milk selling points in Wajir town. Before deciding on the siting of investments, the project's market assessment also mapped camel milk corridors in Wajir county (Kuria and Gitonga, 2016).

In parallel, the project also built the capacity of the Wajir county government to better support policy and planning around rangeland and water management, including establishing a Geographical Information Systems (GIS) lab and supporting the first countywide resource mapping exercise. This involved participatory GIS mapping, which combines satellite mapping with in depth consultations around resources with community experts and communities to maximise community benefits.[11]

As a result of this, the team identified the village of Hadado as a good location for its pilot activities. Here, the project organised 56 women camel milk traders into cooperatives, provided solar-powered milk chilling units with 2,000 litre capacity and hygienic milking cans, as well as offering cost shares on milk transport to Wajir town and provision of training on hygiene and

11 For example, during the exercise, one community rejected a proposal for additional boreholes from the county water department, maintaining that they would result in overgrazing and depletion of rangeland. For further information, see: http://www.braced.org/news/i/?id=06b8ea8a-4164-4518-b8e4-c32d2646d81f

milk handling for herders and traders/ retailers.[12] The project also identified a private sector investor from Wajir, Nourishing Nomads Ltd, who committed to building a modern milk processing plant in the county at an estimated cost of £1.5 million. In addition, the project's research was used to influence the Wajir county government to support key infrastructure investments along five milk supply corridors not covered by PROGRESS, totalling about £400,000 of European Union funding for bulking centres and solar chilling (Gitonga, 2017). This includes funding for remote and smaller solar coolers (25 litre) to be set in satellite centres to capture and chill evening milk and amounts to over 20 times the initial investment provided by the project.

3.2 Approaches in the Sahel: climate-resilient infrastructure for market garden activities

Many rural areas in the dry tropics of SSA face a chronic shortage of vegetable and fruit crops, particularly during the dry season, while prices for such crops remain relatively high year round, and they offer farmers the opportunity to cultivate numerous crops and tailor cropping patterns in response to local conditions (Jayne et al., 2010). Such diversification into high-value crops may be particularly important for poverty alleviation in SSA, especially in West Africa, given the decline in per capita landholdings among smallholders and the volatility in staple crop prices. Evidence suggests that the use of small-scale water irrigation for market garden activities[13] to promote diversification among vulnerable farmers could substantially improve returns to labour and land, help in diversifying risks and provide possible linkages to a broader array of local markets (Burney and Naylor, 2012). In the context of erratic weather conditions currently amplified by climate change, irrigation development has the potential to increase the resilience and productivity of the agriculture sector. In the Sahel, market gardening during the dry season has been promoted as a way to improve the resilience of smallholder farmers since the long droughts of the 1970s and 1980s and their impact on rain fed crops and cattle. This activity is now more at risk, with growing temperatures leading to higher evapotranspiration. The need to adapt small-scale irrigation to this new constraint is a rising issue. Given projected climate changes across the region, technologies that use water efficiently and solar-based technologies should become increasingly more valuable over time.

However, research also suggests that interactions between infrastructure investments and local institutional contexts should be considered with regard to both potential pitfalls and synergies. In particular, while farmer groups can facilitate the sharing of risks, costs and knowledge, there is a need to better understand behaviours in group investment settings. For example, in Benin, Calderone et al. (2018) show that, among farmer organisations targeted for financial support with irrigation improvements, results in terms of improved yields were heterogeneous depending on the land management

12 For further information, see: http://www.braced.org/news/i/?id=e85c0343-8c9f-4b14-be72-dfb232107b09

13 A market garden is the relatively small-scale production of fruits, vegetables and flowers as cash crops.

style preferred. Farmer organisations that use common plots compared with individual plots achieve higher yields (possibly because of learning effects), whereas production based on shared plots is less efficient – especially for market gardens. Better understanding of such dynamics is particularly relevant with respect to uncertainties surrounding groundwater and surface water availability, fuel prices for irrigation pumps, market saturation and infrastructure failures that could be exacerbated by climate change (Burney and Naylor, 2012).

Hence, ASAP and BRACED investments in climate-resilient and -smart irrigation and small-scale community infrastructure has striven to combine hard and soft infrastructure interventions. Also, note that in Chad and Mali both ASAP and BRACED have been implemented and, therefore, further research could explore whether there have been synergies between the two programmes.[14]

3.2.1 BRACED in Burkina Faso

Burkina Faso ranks 161th out of 181 countries on the ND-GAIN index (2017). It ranks 162th on vulnerability and 157th on readiness, showing very poor readiness and high vulnerability. Climate projections for the country include 1.6–2.8°C increases in temperatures by 2050 and increases in the duration of dry spells and heat waves, as well as in frequency and intensity of heavy rainfall (2017).[15] In the agriculture sector, this can lead to reduced soil moisture and crop failure owing to higher climate variability.

Recent national assessments implemented by the World Bank show that, despite large potential, irrigation remains underdeveloped and underexploited in Burkina as the country enjoys relatively abundant water availability, with current agricultural withdrawals for irrigation representing a fraction of total renewable water resources and annual recharge (World Bank, 2018, 2019). In line with such evidence, moving from rain-fed crops to irrigated crops is the strategy emphasised in the National Programme for Economic and Social Development for the agriculture sector (World Bank, 2019). This is also one of the goals of the BRACED project working in the country, which is known as BRES.

Implemented by Welthungerhilfe (WWH), BRES aims to build the economic, ecological and organisational resilience of rural people and strengthen their ability to cope with the effects of increased rainfall variability and higher temperatures by diversifying agricultural production and increasing farm incomes. Hence, a main component of BRES focuses on rural enterprise development and soil fertility improvement through, among other interventions, support to small-scale infrastructure.

To consolidate efforts in income diversification, BRES introduced solar pumps in market gardens relying on wells, while deepening wells that were too shallow, and supplied conventional motor pumps with a relatively larger capacity to market gardens with access to reservoirs and/or dams. However, during implementation, the project realised that increasing

14 For further information on Mali, see http://www.braced.org/news/i/Climate-resilient-programmes-in-Mali-What-we-know-and-how-to-do-it-better/

15 https://www.climatelinks.org/sites/default/files/asset/document/20170807_USAID%20ATLAS_FFP_BurkinaFaso.pdf

weather variability was posing a series of constraints to the sustainability of the supplied infrastructure. Challenges included the need for frequent infrastructure repairs and the dropping of the groundwater level and the water level in wells at the end of the dry season, combined with the fact that most wells had been dug at a depth of between 9 and 12 metres. This increased the risk of there being insufficient water for market garden production, especially in years with substandard rainfall or rainy seasons with a premature end. In addition, the solar pumps the project supplied were not very suitable for pumping water at depths of 10–12 metres.

To ensure the sustainability of market garden operations, the project made producer groups (not just those formally organised as cooperatives but also informal producer groups) aware of the need to set up a system of member contributions to invest in inputs and cover the operating costs of pumps (e.g. diesel) and the basic maintenance of equipment. To explore further options for sustainability and climate resilience, the project also worked in collaboration with the International Institute for Water and Environmental Engineering (2iE). Considering the future climate risks for Burkina, the 2iE Institute advised deepening wells (beyond 12 metres) or rather to drill boreholes and invest in submersible pumps. 2iE also advised reducing the number of beneficiaries per hectare, so that the operations would be more profitable for each beneficiary (2iE, 2019). Hence, WWH is planning to focus future investments in this direction, along with a focus on supporting water-efficient irrigation techniques – such as micro-jets. Moreover, the project linked market garden beneficiaries with the Plant Clinic system implemented by the Ministry of Agriculture and Food Security. This offers agricultural extension services with a focus on phytosanitary matters to prevent and treat plant pests and diseases – such as advice on the treatment of the recent fall army worm infestation.[16]

3.2.2 ASAP in Chad

Chad ranks 180th out of 181 countries on the ND-GAIN index (2017) and is among the worst-performing countries in terms of both vulnerability and readiness. The country has very limited to no readiness, while being one of the most vulnerable countries to climate disruptions. As for the rest of the West African Sahel, climate projections for the country include 3–6°C increases in temperatures by 2100 and increased occurrence of extreme droughts and erratic rainfall, along with increased inter-annual variability in rainfall with sudden oscillations between very wet and very dry years (2017).[17]

Rural households account for 86% of the population, meaning that agriculture is the main source of income for the majority of the labour force. Climate risks, food insecurity and structural vulnerability particularly affect the Sahelian belt of the country, where farmers have to face various climate shocks such as drought, rainfall deficits, flash floods and locust invasions, which are substantially reducing yields.[18] To

16 For further information, see https://www.reuters.com/article/us-burkinafaso-drought-agriculture/in-drought-hit-burkina-faso-the-plant-doctor-is-in-idUSKCN0X41OL

17 https://www.climatelinks.org/sites/default/files/asset/document/2017%20April_USAID%20ATLAS_Climate%20Change%20Risk%20Profile%20-%20Sahel.pdf

18 https://www.ifad.org/en/web/knowledge/publication/asset/39572907

tackle these issues, Chad was among the early beneficiaries of ASAP investments – receiving $5 million in 2014 to support the Project to Improve the Resilience of Agricultural Systems in Chad (PARSAT).

PARSAT aims to support the sustainable intensification of production systems that have proven resilient to climate variability, such as market gardens. To reach this goal, one component of the project focuses on improving the collection and management of agricultural water by constructing or repairing water collection infrastructure, considering the varying physical and socioeconomic conditions of each area. More specifically, under PARSAT, market gardening sites have been equipped with dozens of boreholes and hundreds of wells (designed to irrigate 18 and 44 hectares, respectively). A recent IFAD mission noticed, however, that sites with wells were experiencing a few episodes of water insufficiency; the boreholes are expected to have a satisfactory flow but are still not functional because of the difficulty in providing solar pumping solutions with the power required. This situation is linked to a lack of knowledge about the water table cycle and groundwater resources.

To solve this issue, the supervision mission has asked the project to invest in a network of piezometers and meteorological stations. As the way this information is used is critical, the project will train local producer organisations to collect and employ this data based on the needs of the market gardens. The national entities in charge of the monitoring of water resources and weather patterns will also be involved. This highlights the need to foster networks involving both farmer organisations and public services, to provide adequate climate and environmental information.

Another key activity of the programme is the construction of small dams to enable flood-recession cropping in valleys where the water flow is intermittent. This type of infrastructure can lead to an extension of cropland in areas where rain-fed agriculture is less possible under future climate trends. In the areas where PARSAT operates, an additional 3,500 hectares are now suitable for flood-recession cropping, with a variety of sorghum that has an average yield of 1.7 tons/ha. To ensure sustainable use of this surface, the project supports the formation of organisations of users and clear land tenure rules. This suggests that programmes should focus not only on the technicalities related to climate-resilient infrastructure but also on the related social issues, and recognise key local actors and their customary rights. There is indeed a need to better understand how to integrate technical requirements with participatory approaches for climate-resilient infrastructure, especially in contexts with constrained local capacities – or limited sources of good quality materials.

4. Discussion and final recommendations

To conclude, this section discusses the implications of the above findings for devising effective strategies to support climate-resilient infrastructure and agricultural value chains.

According to Hallegatte et al. (2019), in fostering resilient infrastructure, the first recommendation is for countries to get the basics right in terms of proper planning of operations and maintenance and defining appropriate institutional mandates and strategies. Kornejew et al. (2019) show that underperforming infrastructure systems are indeed largely explained by poor management and governance. Hence, proper integration of climate change in the planning and maintenance of infrastructure at different levels should be consistent with countries' national and local priorities and be supported by regional, national and community plans.

This means that climate-resilient infrastructure investments need to consider the local context, especially the physical and human resources available. This requires integrating technical considerations with participatory approaches, and also ensuring equitable access to resilient infrastructure. Evidence from ASAP and BRACED examples shows how important it is to ensure the buy-in of local stakeholders and to invest in capacity-building support for local institutions managing the infrastructure, as this can significantly contribute to the sustainable management of assets. Moreover, new approaches for the design of climate-resilient infrastructure should enable more comprehensive assessments of spatial priorities, while risk appraisals should look beyond asset losses and take into account secondary impacts on local communities, households and businesses. Besides the improvement of climate projections, it is then essential to create, in cooperation with local authorities, new user-friendly climate services and mapping products suitable to solving current challenges.

There is also a need to support appropriate financing for climate-resilient infrastructure planning, construction and maintenance. Resource mobilisation plays a crucial role in fostering risk-informed development and the development community should do more to find common financial and risk-transfer mechanisms (Opitz-Stapleton et al., 2019). Research on innovative funding mechanisms for resilient infrastructure is growing, but recent studies, for example on the role of resilience bonds, tend to focus on large-scale infrastructure (Lloyd's, 2018; Meyer and Schwarze, 2019). There is a need to better understand which initiatives and financing modalities are suitable for infrastructure investments at the local level. For instance, the example from ASAP/PASP suggests that investment support facilities targeted to agri-businesses to access credit for integrating climate-smart features in construction can be successful, but issues linked to financial literacy and client protection should be taken into account.

At a higher level, climate resilience considerations should be introduced into the regulations and incentive systems of infrastructure sectors and value chains. As ASAP is implemented through government projects, it is well positioned to have a direct impact on national policies. For example, in Rwanda it managed to incorporate climate-resilience design specifications into the national Building Code. A few organisations and project preparation facilities, such as the Global Facility for Disaster Reduction and Recovery, the Global Infrastructure Facility and the emergent Coalition for Disaster Resilient Infrastructure, are already active in these domains, but these remain small compared with the magnitude of the needs.

More broadly, ensuring that infrastructure decisions are made with a proper consideration of climate risks will require decision-makers at all levels in the public and private sectors to review their current approaches to infrastructure planning and project assessment. To avoid locking the economy in a state of future climate vulnerability, it is essential to understand the implications of different design options over future climate scenarios and, therefore, to improve decision-making through data and analysis tools on the spatial distribution of natural hazards. For this, there is a need to establish common data sources, which could be made available to the public, and to leverage the knowledge of the private sector. A couple of dedicated initiatives exist, like Enhancing Climate Services for Infrastructure,[19] but further efforts are required to make real progress.

Investing in data collection at regional or community level is also key, to improve the knowledge on variables such as water resources and deforestation trends. This kind of data can be critical to design climate-resilient and -smart infrastructure, which must be planned with a landscape perspective and a participatory approach, to include local governments and actors.

19 https://www.giz.de/en/worldwide/57471.html

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