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Smallholder Farmers Adaptation to Climate Change: Adaptive Capacity among Ndiwa and Chamazi Farmers in Usambara Highlands, Tanzania

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Abstract

Climate change is one of the major threats to agricultural production worldwide, including many parts of Tanzania. However, different rural agricultural systems are affected differently and differ in their adaptive capacities. This paper assessed the adaptive capacity to climate change by farmers engaged in *ndiwa* and *chamazi* traditional irrigation farming systems in West Usambara Highlands , Tanzania. The study leading to this paper was conducted in four villages: Shashui, Nkukai, Lunguza and Kivingo in Lushoto District; and it adopted a cross-sectional research design involving a sample of 380 households. Data were collected through household survey, Focus Group Discussions (FGDs), observations and documentary reviews. Undeniably, farmers are not poor of what and how to adapt with climate change: they have some knowledge on what they can do to reduce and contain the adverse impacts of climate change. The results show that whereas *ndiwa* farmers have moderate adaptive capacity (41.6%), *chamazi* farmers have low adaptive capacity (23.6%) to climate change impacts. Despite this difference in capacities, both farmers are affected by low financing (*ndiwa* (14.36%), and *chamazi* (8.48%) as grants or credits hardly reach small-scale farmers; low access to technical information (*ndiwa* (15.08%), and *chamaz*i (5.17%)); relative low access to physical infrastructure (*ndiwa* (5.02%), and *chamazi* (3.02%)); relative low level of diversity of livelihood (*ndiwa* (4.56%), and *chamazi* (4.49%)); and relative low level of human resources (*ndiwa* (2.51%), and *chamazi* (2.35%)). The paper recommends that strategies for enabling farmers to become change agents of climate change should build capacity in areas of physical resources such as equipment and infrastructure for irrigation, access to climate information, access to financing opportunities, livelihood diversification, and storage.

1. Introduction

Tanzania is one of the Sub-Saharan Africa (SSA) countries in which agriculture is the backbone of the economy (Masamba et al., 2018). Tanzanian agriculture is the major source of food; and accounts for about 45% of the GDP, 60% of merchandise exports, 75% of rural household income, and 80% of employment

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(Komba & Muchapondwa, 2018). Despite the relatively large proportion of the population that depends on agriculture, the sector is still dominated by smallholder farmers with small farm sizes and relatively low productivity (Kihila, 2018). Factors that contribute to low agricultural productivity include the use of poor farming methods (technologies), and much dependence on rainfall and weather conditions (Karimidastenaei et al., 2022). All these factors make smallholder[1] farmers in Tanzania to be very vulnerable to climate change (Coffinet et al., 2018; Ilyas et al., 2021; Ngcamu, 2023).

Traditional irrigation farming (TIF)[2] is among the farming systems in Tanzania that play a significant role in ensuring food security and income generation to smallholder farmers (Kaganzi et al., 2021; Said et al., 2021; Weerahewa et al., 2023). For instance, '*mifongo*'[3] and '*vinyungu*'[4] have been playing significant roles in the livelihood of farmers in Kilimanjaro and Iringa regions, respectively (Van der Plas et al., 2021; Jambo, 2021). Traditional irrigation farming, like other farming systems, faces challenges due to changes in temperature, hydrological conditions and incidences of pests and diseases to crops mainly contributed by climate changes (Jha, 2023). These changes have impact on crop yields, food security, dependence on forest resources for livelihoods, and the migration of people to lowlands and urban centres (Leal Filho et al., 2022).

Adaptation to climate change is increasingly recognized as a necessary complementary measure to mitigate the effects of climate change in different parts of the country (Pardoe et al., 2018). Available research information suggests that many farmers in different parts of the country adapt through increased use of drought-tolerant local crop varieties, extensive planting, mixed cropping, agroforestry, opportunistic weeding, switching to non-farm activities, selling assets, and wild plant gathering (Ansah et al., 2019; Nzabarinda et al., 2021; Guodaar et al., 2021). Field-level experiences show that these adaptation strategies vary widely within communities with respect to their adaptive capacity[5] (Fazlier et al., 2019). Thus, the understanding of adaptive capacity of a community is important when developing and implementing effective adaptation strategies to reduce the harmful outcomes resulting from climate change (Cinner et al., 2018). Knowing where strengths

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[1] Smallholders describe rural agriculture producers in developing countries who usually cultivate less than one hectare, use family labour, and employ poor faming tools and methods.
[2] Traditional irrigation is the application of water to a farm using indigenous water harvesting techniques that are not based on scientific understanding, but locally developed knowledge.
[3] *Mfongo* (pl. *mfongo, mifongo*) is a furrow or ditch in Chagga language spoken in the Mt. Kilimanjaro area. It describes a traditional furrow irrigation through stream diversions in the hills.
[4] Vinyungu refers to traditional irrigation farming that utilizes natural moisture or water from either natural springs or diversions in valley bottoms or plains; commonly practices in Iringa, Tanzania.
[5] Adaptive capacity is the ability or potential of a system to cope with or respond successfully to climate variability and change, and includes adjustments in both behaviour and in resources and technologies.

and weaknesses exist allows practitioners to take advantages of higher capacity areas and enhance lower capacity areas to build resilience in the community or system (Cinner et al., 2018). By drawing a case of smallholder farmers engaged in *ndiwa*[6] and *chamazi*[7] traditional irrigation farming in West Usambara Highlands, this paper aims to analyse the adaptive capacity of smallholder farmers in adapting to climate change. It also seeks to offer evidences of capacity building invested in smallholder farmers by national and international climate change support systems. Also, the paper seeks to answer questions such as: Are traditional irrigation farmers capable of adapting to climate change? If so, what areas of adaptive capacity are smallholder farmers strong or weak? These questions contribute to issues of opportunities and challenges of food production, as well as ways of transforming rural farmers in the face of climate change challenges in Tanzania.

2. Materials and Methods

The study that yielded data for this paper was conducted in four villages: Shashui, Nkukai, Lunguza and Kivingo within Lushoto district, Tanzania (Figure 1). The study villages were selected largely by considering the following criteria: the existence and operation of traditional irrigation farming; dependence on agriculture by the majority of the population as their major economic activity; existence of traditional irrigation farming that represents the humid and semi-arid farming environment; and the accessibility of the villages by the research teams.

In the selected study area, a total of 380 households were involved in the research. This sample was obtained in two stages. First, the sample size was estimated from the total number of households using the formula developed by Gibson (2018), with a confidence level of 0.05. Second, the estimated sample size was used to compute the proportion of the sample (households) in each village based on the number of households for each village (Table 1).

Table 1: Sample Size and Distribution

#	Village Name	No. of Household	Sample Size	Percentage
1	Shashui	3430	173	45
2	Nkukai	1496	75	20
3	Lunguza	1132	57	15
4	Kivingo	1500	75	20
	Total	**7558**	**380**	**100**

[6] *Ndiwa* is a vernacular word of the Sambaa people in West Usambara Highlands meaning an overnight reservoir or farm-pond.
[7] *Chamazi* is a vernacular word of the Sambaa people in West Usambara Highlands meaning the use of residual moisture in valley bottoms for crop production.

Source: Village Registers. (2022)

Figure 1: Map Showing the Study Villages in Lushoto District

Source: University of Dodoma GIS Laboratory (2022)

Regarding sample selection, specifically purposive sampling was employed in the following manner. Firstly, from the stratified wards, four wards—namely Soni and Sunga (humid areas), Lunguza and Kivingo (semi-arid areas)—were purposely selected. Secondly, from the selected wards, purposive sampling was used to select a total of 4 villages for the study. These were: Shashui and Nkukai (located in humid climatic condition); and Lunguza and Kivingo (located in semi-arid climatic condition). Thirdly, purposive sampling technique was used to select a total of 8 key informants (experts), i.e., two experts from each village. Probability sampling—specifically employing simple random techniques—was employed to select 380 households. The selection was done by randomly picking a name without replacement when choosing the second one, and so on.

Different methods and techniques were adopted to collect primary data to triangulate information and ensure validity (Busetto, 2020). A household survey was conducted using pre-designed questionnaires aimed to collect specific data for each potential indicators and sub-indicators of adaptive capacity and characteristics of households. This was followed by focus group discussions (FGDs) and key informants (experts) interviews. Also, the study made use of secondary data from maps, statistical abstracts, and scientific reports as additional sources. Farmer's fields were also visited to have a physical overview, and verify information collected during the household surveys and FGDs.

In assessing the level of adaptive capacity of *ndiwa* and *chamazi* farmers, this paper adopted and modified the methodology suggested by Siders (2019) and Chepkoech et al. (2020). The methodology involved the use of indicators commonly known as the determinants of adaptive capacity, and a scoring system that involved the identification of adaptive capacity indicators based on a sustainable livelihood (SL) framework (DFID, 1999; Natarajan et al., 2022); assigning weights to indicators and sub-indicators using expert's opinion; calculating the priorities of indicator and sub-indicator using analytical hierarchy process (AHP) (Moslem et al., 2023); aggregating all indicators and sub-indicators scores and coming up with score ranging from 0 to 1 or (0% to 100%) for adaptive capacity. It also involved the classification of scores into three levels: low adaptive capacity (L), moderate adaptive capacity (M), and high adaptive capacity (H), with cut-points based on the classification used by Richard and Douglas (2014) and Owen (2020)—i.e., 0 to 33% =low (L); 34 to 66%=Moderate (M) and 67 to 100%=High (H). Moreover, the method involved collecting households data from for each indicator and sub-indicator via household survey.

The collected data were then analysed using descriptive statistics to obtain percentage distribution of farmers in each indicator/sub-indicator. However, the adaptive capacity scores for each indicator/sub-indicator was obtained by taking the product of percentage distribution of farmer's characteristics and weight with respect to indicator/sub-indicator. To determine the overall adaptive capacity, the research adopted the method from MacRitchie and Stainby (2011) and Mekonen and Berlie (2021), which involves adding the scores for each indicator and sub-indicator. The judgment on the adaptive capacity was based on the overall score of all adaptive capacity indicators/sub-indicators.

3. Results and Discussions

The adaptive capacity to climate change (for farming households) is influenced by the diversity of its livelihood and the physical, human, financial and information resources the households own and have access to (Siders, 2019; Chepkoech et al., 2020). These indicators are important factors that determine resilience to shocks such as climate variability or change. They comprise the assets or activities that reduce risks, smoothen consumption and maintain standards of living in the event of catastrophes or disruptions in farming (Godde et al., 2021). In determining the level of adaptive capacity of *ndiwa* and *chamazi* farmers, this paper investigated assets ownership, strengths and resources available to *ndiwa* and *chamazi* farmers as stipulated in the methodology section. The results are detailed below.

3.1 Adaptive Capacity Indicators and Levels

Smallholder farmers have diverse skills and knowledge for adapting against climate change (Chukwuemeka & Agoh, 2022). Nevertheless, their adaptive capacity varies geographically, and it is influenced by various factors. Hence, understanding the determinants of their adaptive capacity makes more sense today when questions and discussions on why are farmers not being able to contain or manage the impacts of climate change. In other words, discussions and research need to go beyond the *what* and *how* do farmers adapt, and concentrate on *why* achievements are limited. Such an analysis is also more significant to offer evidences whether governments and international support systems are reaching smallholder farmers. Table 2 summarizes the key determinants of adaptive capacity, and the way farmers access them.

Table 2: Relative Importance (weights) of Adaptive Capacity Indicators

Adaptive Capacity Indicator	Weight (%)	Adaptive Capacity Sub-indicator	Weight (%)
Financial resource	36.4	Remittance	18.4
		Assistance from government	11.5
		Access to credit	6.5
Information	26.5	Training	10.7
		Technical assistance	9.1
		Participate in farm organization	6.7
Physical resources	17.6	Farm size	2.3
		Farm tenure	4.6
		Irrigation	7.3
		No. of farm machines owned	3.4
Diversity of livelihood	13.2	Number of livelihoods	8.4
		Number of crop planted	4.8
Human resources	6.3	Farm experience	2.1
		Education level of household head	3.5
		Percentage of adult household members	0.7
Total	**100**	**Total**	**100**

Source: Field Survey AHP Analysis, 2022

Table 2 shows that financial resource scored more weight (36.4%) compared to other adaptive capacity indictors. According to Siders (2019) and Chepkoech et al. (2020), adaptation requires monetary expenditures: higher financial resources make possible for the acquisition of physical and information resources vital in carrying out adaptation. Information resource was ranked the second, weighting 26.5%. The experts (agricultural extension and irrigation officers) in the study area felt that pertinent knowledge is important for farmers to come up with effective adaptation strategies. The weights of the other resources are 17.6%, 13.2% and 6.3% for physical, livelihoods diversity, and human resources, respectively. Hence, an analysis of how smallholder farmers in West Usambara Highlands rank the value of each of these determinants and the way they acquire—or are empowered to access—them is significant.

3.1.1 Financial Resources

The results in Table 3 show that the total scores for *ndiwa* and *chamazi* farmers on financial resources as adaptive capacity indicators were 14.36% and 8.48%, respectively. These scores are far below the expert's (agricultural extension and irrigation officers) weight value of 36.4%. This means that *ndiwa* and *chamazi* farmers have low access to financial resources. This low access to financial resources reduces their ability of having sufficient financial resources necessary to buy basic equipment and materials for irrigation improvement and adaptation to climate change.

Table 3: Distribution of Farmers' and Scores by Financial Resource Sub-indicators

Weights of indicators and sub indicators based on expert's opinion (%)			***Ndiwa* (n= 248)**		***Chamazi* (n=132)**	
Indicator	**Sub-indicator**	**Categories**	**Farmers (%)**	**Score (%)**	**Farmers (%)**	**Score (%)**
Financial resource	Remittance	Yes	46.9	8.63	27.8	5.12
		No	53.1	0	72.2	0
	Assistance from government	Yes	36.4	4.19	18.2	2.09
		No	63.6	0	81.8	0
	Access to credit	Yes	23.7	1.54	19.6	1.27
		No	76.3	0	80.4	0
Total Score				**14.36**		**8.48**

Source: Field Survey AHP Analysis, 2022

In addition, this article looked into whether farmers receive significant support from the government and/or financial institutions. The results from IPCC (2022) show that Africa received a total of US$16,489m of financial support from bilateral and multilateral institutions committed to climate change. Of this support, East Africa led by US$5630m, Western Africa (US$4816m), North Africa (US$2619m), and Southern Africa (US$2059m). By 2022, Kenya was the country leading in receiving funds (US$3216m), while Tanzania received US$1775m (Figure 2). However, the study results show that the number of *ndiwa* and *chamazi* farmers receiving financial assistance via remittance is relatively higher than that through government and formal financial institutions. Also, social capital works effectively in supporting farmers than financial support from the government. Consequently, we should not wonder why results from climate change adaptation are trivial: farmers are struggling from limited financial support.

Figure 2 indicates that while the USA and UK committed US$900m and US$1313m, respectively, China, Russia, Japan do not feature in the top 10 countries investing in climate change support. These statistics shows that the world has not done much in financing farmer's activities to enable them transformed from traditional irrigation techniques to more advanced ones in the face of climate change.

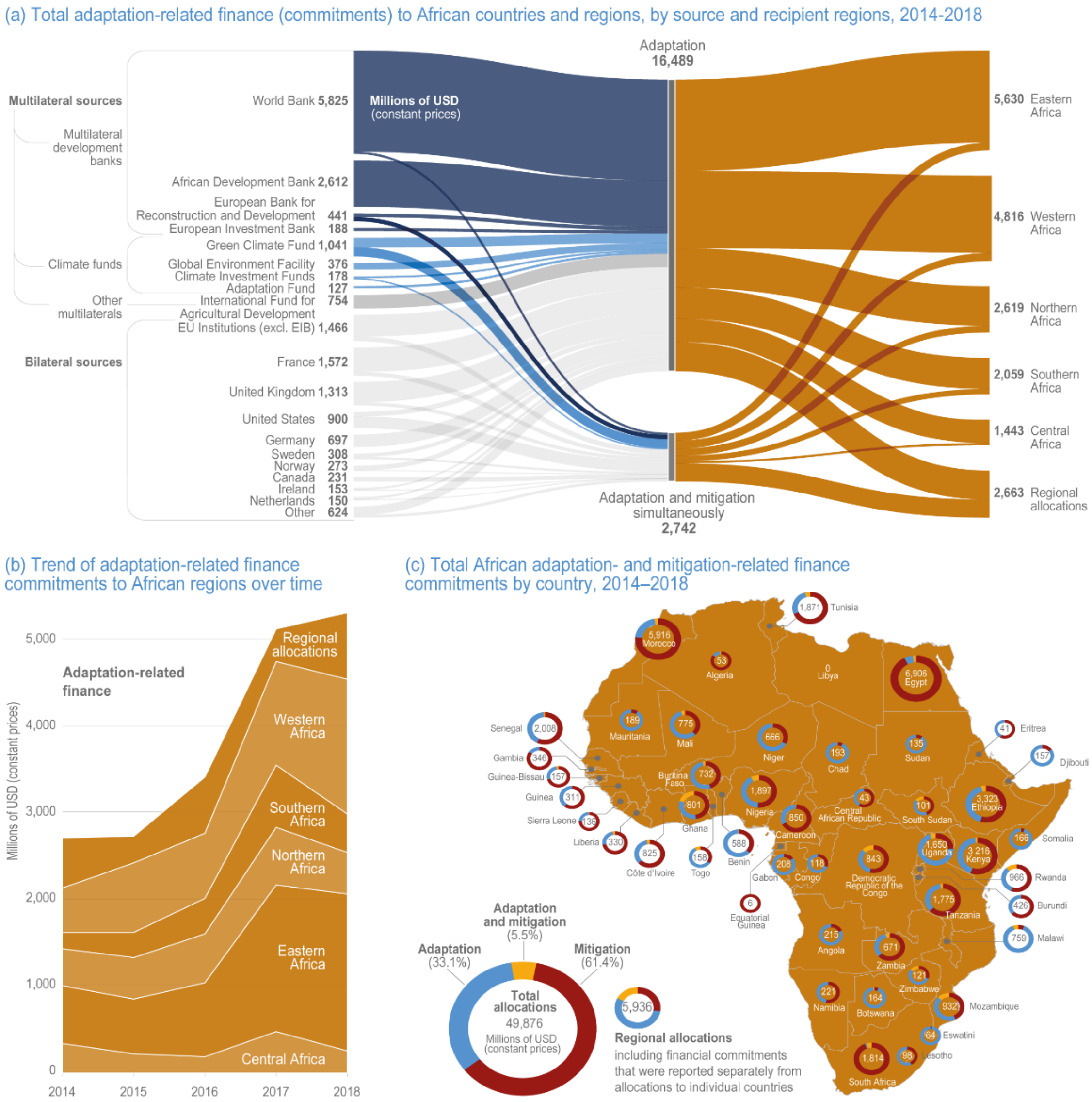

Figure 2: Financial Commitments Targeting Africa

Source: IPCC, 2022

During the study, the District Agricultural Irrigation and Cooperative Officer in Lushoto pointed out further that, even accessing formal credit from banks is still a challenge for farmers because the majority lack collateral for loans. According to Nyawo and Mubangizi (2021) and Agandaa (2023), the lack of collateral, fear of assets loss submitted as security, and long distance to banks: all force smallholder farmers in Africa to rely on expensive credit from informal sources; which in turn increases vulnerability to climate change impacts.

3.1.2 Information

Access to information is another determinant for adapting to climate change. Information on the trend of rainfall and temperature, and/or climate related hazards, are meant for farmers to take precautions (Gebru et al., 2020). This article was motivated with the question on whether farmers were receiving timely, valid and adequate climate information.

Table 4 shows that the total scores for *ndiwa* and *chamazi* farmers on information resources as adaptive capacity indicators were 15.08% and 5.17%, respectively. These scores are far below the expert's weight value of 26.5%. This shows that *chamazi* farmers have relatively low access to information resources in the form of agricultural-related trainings, technical assistance, membership to farmers' organizations, and access to climate information compared to *ndiwa* farmers. During household surveys in Lunguza and Kivingo villages, it was noted that the relative low access to technical assistance for *chamazi* farmers is contributed by the shortage of agricultural extension and irrigation officers. Field observation in Lunguza and Kivingo villages revealed that there was only one agricultural extension and irrigation officer serving *chamazi* farmers in the two villages.

Table 4: Distribution of Farmers and Scores by Information Resource Sub-indicators

Weights of adaptive capacity indicators and sub indicators based on expert's opinions (%)			***Ndiwa* (n=248)**		***Chamazi* (n=132)**	
Indicator	***Sub Indicator***	***Categories***	***Farmers %)***	***Score (%)***	***Farmers (%)***	***Score (%)***
Information resource	Training	Yes	54.6	5.84	12.3	1.32
		No	45.4	0	87.7	0
	Technical assistance	Yes	56.5	5.14	28.2	2.57
		No	43.5	0	71.8	0
	Participate in farmers organization	Yes	68.7	2.95	10.4	0.45
		No	31.3	0	89.6	0
	No of sources of climate information	None	5.0	0	18.6	0
		1 source	46.4	0.42	64.1	0.58
		2 and above sources	48.6	0.73	17.3	0.26
Total Score				**15.08**		**5.17**

Source: Field Survey, 2022

From the results on access to agricultural trainings, it can be concluded that the observed low access to agricultural training and technical assistance by *chamazi* farmers reduces their adaptive capacity to climate change compared to the *ndiwa* farmers. This is because agricultural trainings play a crucial role in providing farmers with knowledge and skills necessary for the adaptation to climate change and variability. Indeed, the shortage of access to information by farmers is an outcome of low investment in research.

The IPCC report of 2022 shows that funding on climate research in Africa was very small: the continent only received US$11.4bn in adaptation finance in the 2019–2020 period (Figure 3). At this rate, Africa will receive US$182bn by 2035 for climate adaptation (Overland et al., 2022). It is apparent that the top 10 country locations of institutions receiving funding for climate research in Africa include the US, UK, Germany, Sweden, Netherlands, Italy, South Africa, Kenya, Norway and France (IPCC, 2022): Tanzania is not among these top 10 countries. It is also imperative to ask ourselves whether Africa is benefiting much from the funding for climate research when leading receivers of such funds are located in the developed countries. Why are institutions receiving funding for climate research in Africa not located in Africa? Was this an accidental or a planned scenario? The persistence of these questions unpacks the reasons why farmers in Usambara Highlands are still hustling with adaptation to climate change.

Membership to farmers' organizations and climate information are other sub-indicator of information resources considered in this paper. According to Siders (2019) and Chepkoech et al. (2020), affiliations to social groups provide farmers' access to useful information for climate change adaptation, which may be exclusively available only to group members. In addition, Parker et al. (2019) observed that group membership can be a significant avenue for knowledge-sharing among farmers about effective climate change adaptation practices. The results in Table 4 show that a large proportion (68.7%) of *ndiwa* farmers participates in farmers' organizations or groups, while it is only a small percentage (10.4%) of *chamazi* farmers who participate in farmers' organizations or groups. Field observations in the study area revealed that the presence of irrigation infrastructures such as *ndiwas* (dams) and irrigation canals shared among *ndiwa* farmers has contributed to their involvement in farmers' groups and organizations compared to *chamazi* farmers.

The results in Table 4 further show that a large proportion (64.1%) of *chamazi* farmers has at least one source of weather/climate information. However, the results show that about 46.4% and 48.6% of *ndiwa* farmers have at least one or two and above sources of weather/climate information. The common sources of weather or climate information in the study area are radio and television.

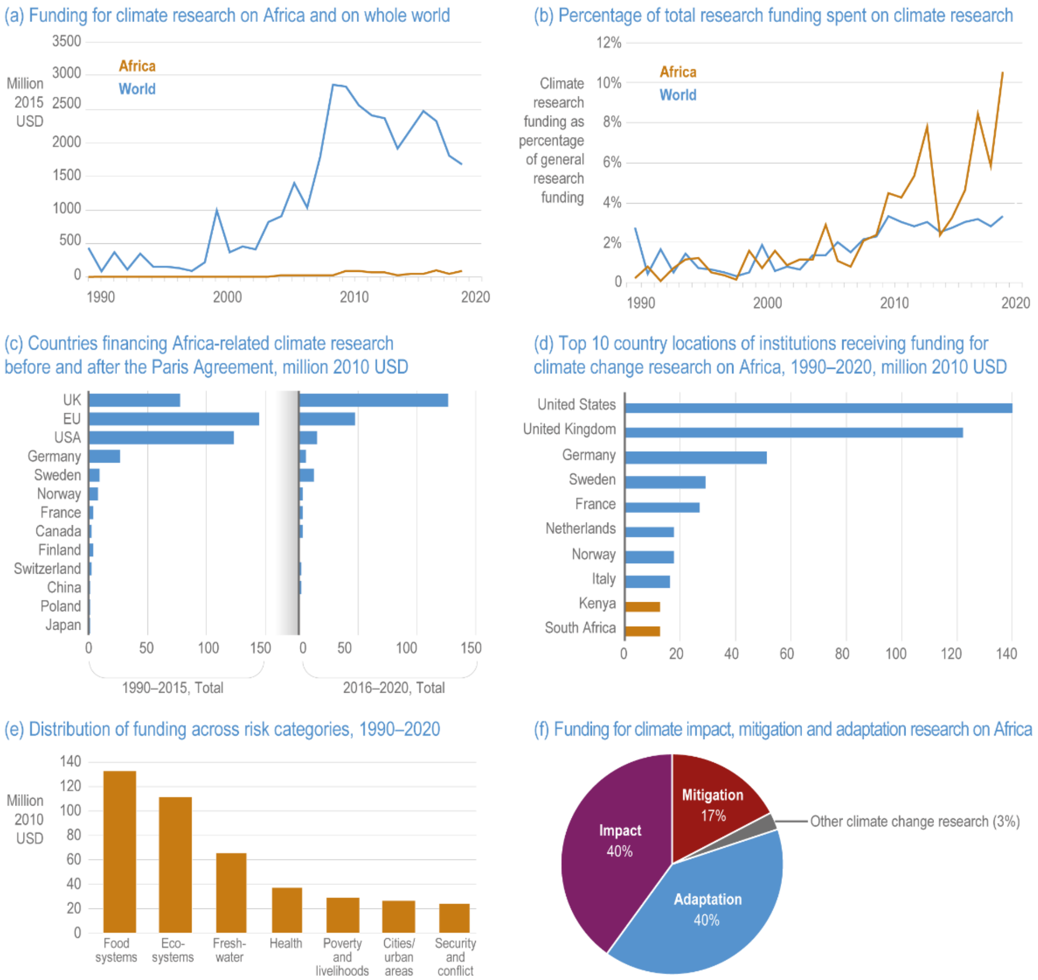

Figure 3: Funding on Climate-related Research in Africa

Source: IPCC, 2022

Weather information is an important input in making farm decisions related to adaptation to climate change (Siders, 2019). Useful climate information—such as on rainfall, temperature, schedule of rainy/dry season, and advice on drought—are important in enhancing farmers' adaptation to climate change (Owen, 2020). Information access is still a hustle for smallholder farmers because of low local research on climate change and participation of farmers themselves in Africa. The number of individual researches on adaptation are higher in North America and some countries in Europe and Australia, which was above 1000 papers by 2022. In South America, most countries had between 601–1000 papers; while Africa had between 201–401 papers, with the exception of South Africa (Figure 4).

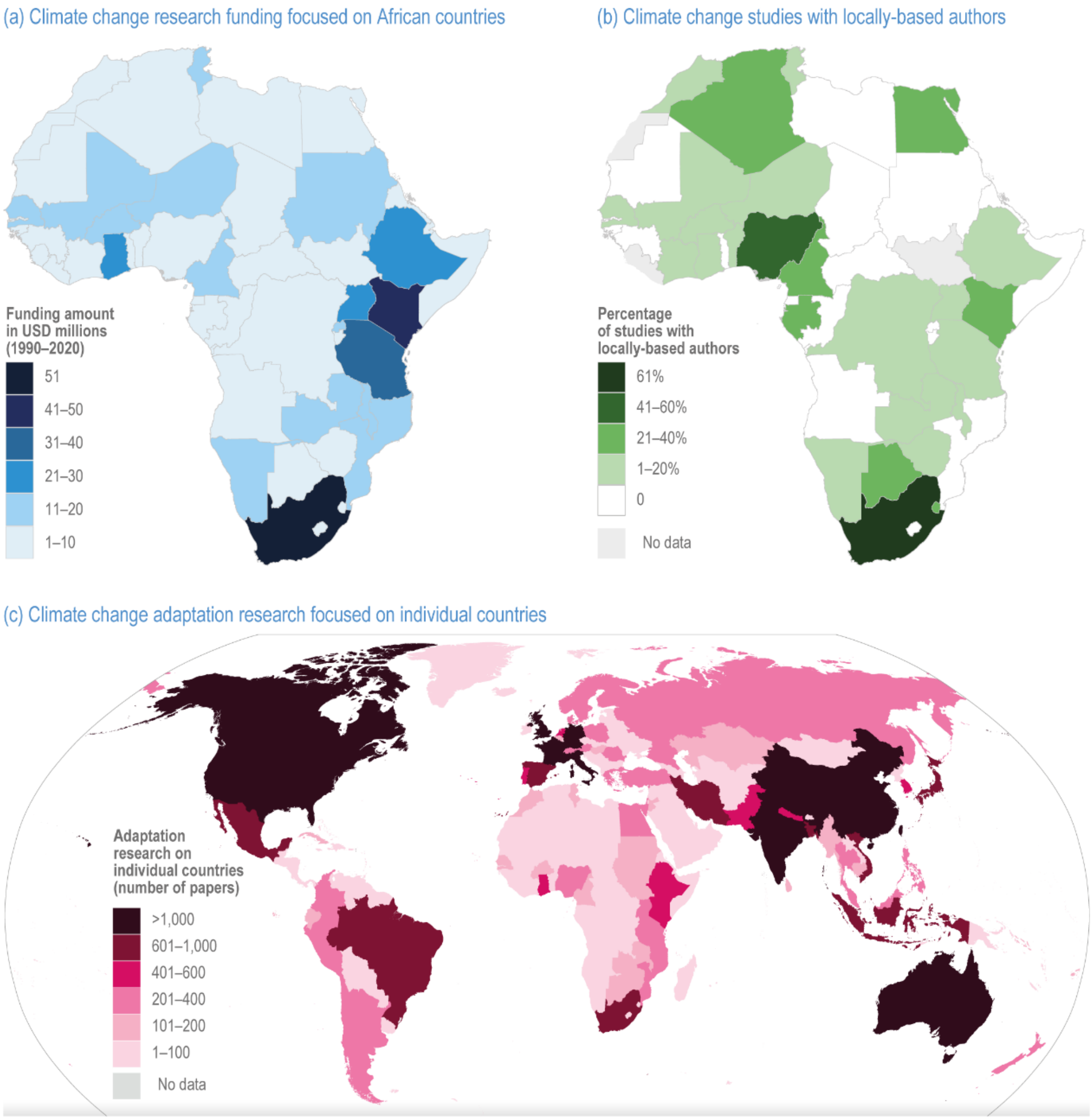

Figure 4: Major Gaps in Climate Change Research Funding, Participation and Publications in Africa

Source: IPCC, 2022

Also, the percentage of studies by locally based authors in Africa shows only in South Africa did it reached 61%; a few countries in the Northern part of Africa reached between 41–60%, while most countries in the rest of Africa publications varied between 20–40%. These results offer two implications on the capacity of smallholder farmers to adapt against climate change. First, most farmers have no sufficient scientific information on how to properly adapt with climate change. Second, the majority rely on traditional knowledge. Again, these results justify the hustles stallholder farmers face in adapting with climate change; with multiple effects in the whole scenario of transformation and utilization of opportunities available in improving food production.

3.1.3 Diversity of Livelihood

The results in Table 5 show that a large proportion—56.5% and 60.8% of *ndiwa* and *chamazi* farmers, respectively—rely on two to three sources of livelihoods. The most common sources of income in the study area are livestock keeping, non-farm employments either in the formal or informal sector, such as in public transportation (i.e., *bodaboda*), construction work, teaching, community leadership and small business. In addition, a large proportion—63.2% and 56.3% of *ndiwa* and *chamazi* farmers, respectively—plant three or more varieties of crops. During FGDs with different groups it was revealed that planting more than one type of crops helped to distribute the risk of crop failure due to diseases and shortage of water. The results on the diversification level in terms of number of crops planted by *ndiwa* and *chamazi* farmers also show high diversifications. According to Mzyece and Ng'ombe (2020), diversification of crops by altering crop varieties and increasing the number of crops to be planted has the potential to increase farm efficiency in the light of changing climatic conditions.

Table 5: Distribution of Farmers and Scores by Livelihood Diversity Resource Sub-indicators

Weights of indicators and sub-indicator based on expert's opinion (%)			***Ndiwa* (n=248)**		***Chamazi* (n=132)**	
Indicator	***Sub-indicator***	***Categories***	***Farmers (%)***	***Score (%)***	***Farmers (%)***	***Score (%)***
Livelihood diversity	Sources/No. of livelihoods	1 source	32.6	0.39	29.9	0.36
		2 to 3 sources	56.5	1.64	60.8	1.76
		4 to 5 sources	10.9	0.47	9.3	0.39
	Variety of crop planted	1 crop	0	0	0	0
		2 crops	36.8	0.48	43.7	0.57
		3 and above	63.2	1.58	56.3	1.41
Total Score				**4.56**		**4.49**

Source: Field Survey, 2022

Moreover, Table 5 show that the total scores for *ndiwa* and *chamazi* farmers on diversity of livelihood resources as adaptive capacity indicators are 4.56% and 4.49%, respectively. These scores are relative below the expert's weight value of 13.2%. From the results it can be concluded that *ndiwa* and *chamazi* farmers have relatively low diversity of livelihood resources. This means that low diversity of livelihood resources by *ndiwa* and *chamazi* farmers reduces their ability to adapt to climate change, with negative implication in food production. According to Maja and Ayano (2021), diversity in crops and income sources enables farmers to create a portfolio of livelihoods with different risk attributes so that risks such as those posed by climate change can be managed, making recovery easier and faster.

In the same vein, IPCC (2022) depicts a mixed picture of adaptation capacity for different regions in Africa. Figure 5 shows that in the area of food fibre and other ecosystem products, African countries demonstrate different capacities. On agroforestry, evidences of its practice in Africa is high; but moderate in Eastern and Western Africa, low in the Southern Africa, and lacking insufficiency evidences in Central and Northern Africa.

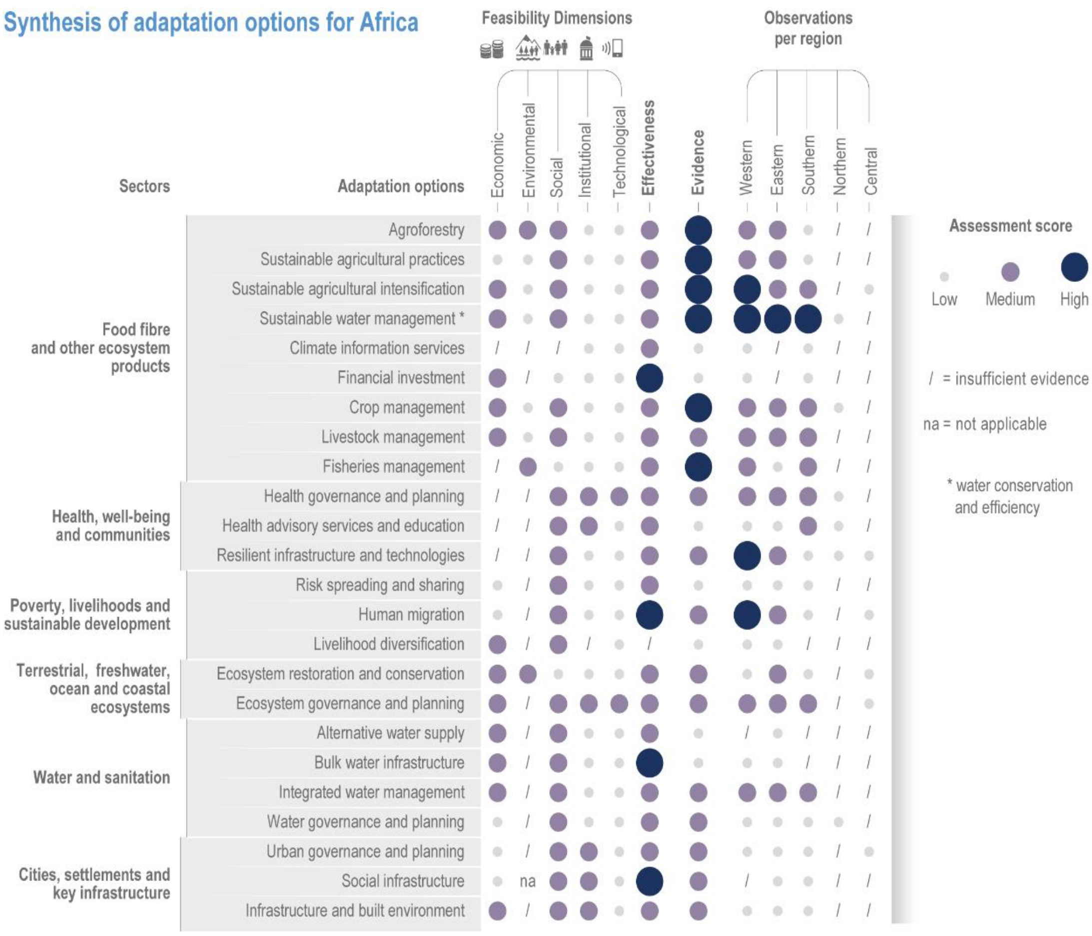

Figure 5: Adaptation Diversities in Africa
Source: IPCC, 2022

On sustainable agricultural practices, observable evidences are high in Eastern and Southern Africa, low in Southern, and lacking sufficiency evidences in North and Central Africa. Agricultural intensification is another strategy reflecting a varying capacity in Africa: it is high in Western, and medium in East and Southern Africa. However, there are insufficient evidences for North and Central Africa. In the area of livelihood diversification, IPCC (2022) unpacks low evidences of investment in Africa: it is low in Eastern and Western, and lacks evidences in Northern and Central Africa. All these narratives offer implications on the efforts to fight climate change in Africa.

Despite the varying adaptive capacities between regions, evidences suggest that Africa has done less on conservation agriculture, and sustainable agriculture. Also, the question of urban planning and infrastructure provisioning for climate change has also not been a matter of significant concern in Africa. Although it is evident that the growth of cities contributes immensely to climate change, less efforts are devoted to contain the cause. It is not a miracle that farmers are struggling with adaptation to climate change.

3.1.4 Physical Resources

Physical resources include natural assets such as land, produced capital like machines and farm infrastructures. The results in Table 6 show that the total scores for *ndiwa* and *chamazi* farmers on the adoption of physical resources as adaptive capacity indicators are 5.02 % and 3.02%, respectively.

Table 6: Distribution of Farmers and Scores by Physical Resource Sub-indicators

Weights of indicators and sub indicators based on expert's opinion (%)			***Ndiwa* (n=248)**		***Chamazi* (n=132)**	
Indicator	***Sub indicator***	***Categories***	***Farmers (%)***	***Score (%)***	***Farmers (%)***	***Score (%)***
Physical resource	Farm size	0.5 to 1.5 acre	65.1	0.26	25.2	0.10
		2 to 3.5 acre	33.5	0.27	64.7	0.52
		4 to 5.5 acre	1.4	0.02	10.1	0.11
	Farm tenure	Individual owner	98.8	1.38	97.0	1.36
		Leaseholder	1.4	0.04	1.0	0.03
		Rent	0	0	2.0	0.01
	Irrigation	Rainfall	20.7	0.10	83.6	0.42
		Rivers	10.3	0.22	9.9	0.21
		Shallow wells	4.5	0.04	4.1	0.03
		Natural spring/dams	64.5	2.52	2.4	0.09
	Farm machines owned	None	86.8	0	89.3	0
		1 to 2	10.2	0.11	8.4	0.09
		3 and above	3.0	0.07	2.3	0.05
Total Score				**5.02**		**3.02**

Source: Field Survey, 2015

Generally, *ndiwa* and *chamazi* farmers have relatively low access to physical resources such as farm size, farm ownership (farm tenure), sources of water for irrigation, and equipment. This low access reduces their ability to adapt to climate change. According to Cinner et al. (2018), natural assets such as land, farm infrastructures (e.g., water for irrigation) act as material wealth to farmers that are necessary in the adaptation to climate change.

With regards to farm tenure systems, the majority (98.8% and 97.0% of *ndiwa* and *chamazi* farmers, respectively) are individual owners of their farms; with farm sizes ranging between 0.5 and 4 acres. According to Siders (2019), farmers with big farm sizes have high adaptive capacity as big farm sizes enable them increase the varieties of crops to be planted, and hence crop yield and income. Individual ownership of farms is the most secure land tenure status, and allows owners the privileges to farm infrastructures such as the construction of shallow tube wells, canals and dams: all of which are not accessible to non-owners (Chepkoech et al., 2020). However, Bukvic et al. (2020) observed that the most secure land tenure status is one that enables farm owners to combine a set of resources to carry out strategies for adapting with climate change. Unfortunately, this is lacking in the study area. Again, although individual tenure systems are widespread, the adaptive capacity of farmers is affected by unregistered farms with no title deeds. This is another hurdle in adapting with climate change because farmers are uncertain of their farm ownership. In view of Village Land Act 5 (1999), land is a public asset under the custody of the president.

On sources of water for irrigation, the majority (83.6%) of *chamazi* farmers rely on rainfall for their farming activities; while a large proportion (64.5%) of *ndiwa* farmers rely on natural springs/local dams (*ndiwa*) for their farming activities. According to Owen (2020), farmers relying on rainfall for farming activities have low adaptive capacity during times of rainfall shortage, compared to those who use other sources such as storage dams and rivers.

The results in Table 6 show that the majority (86.8% and 89.3% of *ndiwa* and *chamazi* farmers, respectively) do not have farm machines such as power tillers, tractors, water pumps, water sprinklers and blowers. Most of the farmers owned simple farming equipment's such as threshers, hand-hoes and bush knifes. The ownership of farm machines enables farmers to exploit better farming technology, hence, enhancing adaptive capacity (Chepkoech et al., 2020). In short, access to infrastructure by farmers is still a challenge not only in Tanzania but in the entire African continent. IPCC (2022) reveals that there are low evidences of access to resilient infrastructure and technologies in Africa. As shown in Figure 4, evidences of access to infrastructure are only high in the Western, moderate in the East, and low in all other African regions. Consequently, farmers are not safe and capable to adapt to climate change due to low ownership and/or access to physical assets.

3.1.5 Human Resources

Table 7 shows that the total scores for *ndiwa* and *chamazi* farmers on human resources as adaptive capacity indicator were 2.51 % and 2.35%, respectively. However, the scores are below the weight value of the experts (agriculture extension and irrigation officers), which was 6.3%.

Table 7: Distribution of Farmers and Scores by Human Resource Sub-indicators

Weights of indicators and sub indicators based on expert's opinion (%)			***Ndiwa* (n=248)**		***Chamazi* (n=132)**	
Indicator	***Sub indicator***	***Categories***	***Farmers (%)***	***Score (%)***	***Farmers (%)***	***Score (%)***
Human resource	Farm experience	Less or equal to 10 years	8.6	0.01	10.6	0.01
		11 to 30 years	36.2	0.33	49.2	0.44
		31 and above years	55.3	0.61	40.2	0.44
	Education level of household head	Informal	13.7	0.01	21.0	0.02
		Primary	74.1	0.96	71.1	0.92
		Secondary	12.2	0.26	7.9	0.17
	Percentage of adults in household	0% to 25%	12.1	0.01	11.3	0.01
		26% to 50%	16.2	0.03	10.5	0.02
		51% and above	71.7	0.29	78.2	0.31
Total Score				**2.51**		**2.35**

Source: Field Survey, 2022

The results in Table 7 show that the *ndiwa* and *chamazi* farmers have a relatively low access to human resources. High human resources such as longer experience, more education and better health means more knowledge and skills to adapt to risks posed by climate change, which rebounds to higher adaptive capacity (Mekonen & Berlie, 2021). This is also another area demanding answers. In this paper, this problem was analysed through farming experience, level of education of household heads, and percentage of adults in a household.

According to the results in Table 7, a large proportion (55.3% and 40.2% of *ndiwa* and *chamazi* farmers, respectively) have farming experience of above 31 years. This means that they are well experienced farmers. It was revealed during FGDs that the majority of farmers started to engage in traditional irrigation at a young age by assisting their parents in farmwork. In terms of farming experience, both *ndiwa* and *chamazi* farmers are in a better condition to adapt to climate change given that other resources are constant. This is consonant with the observation by Godde et al. (2021): that farmers with more farming experiences are expected to adapt better to climate change as they are capable of utilizing knowledge and skills acquired from the long historical practices.

Moreover, Table 7 shows that a large proportion (74.1% and 71.1% of *ndiwa* and *chamazi* farmers, respectively), have primary education: a relatively a low level of education that affect farmers to adopt new skills, conservation agriculture and the acquisition of climate information. According to Siders (2019), more educated farmers have better access to information and technologies; hence they are better able to exploit these resources in adapting to climate change.

Available labour force is also an indicator of adaptive capacity. The percentage of adults in a household refers to the number of people in a family who can support themselves. This implies that households with higher percentage of adults have higher adaptive capacities because they have more available labour and less dependent persons to support (Siders, 2019; Chepkoech et al., 2020). Table 7 show that a large proportion (71.7% and 78% of *ndiwa* and *chamazi* farmers, respectively) have more than 51% of working adults. From these results, it can be concluded that—other conditions being constant—many of the *ndiwa* and *chamazi* farming households have high adaptive capacity because they have high available labour and low dependants.

Figure 6 shows that the climate change literacy levels of the majority of African countries lie between 40–49%; very few are between 60–69%; and a remarkable number have their levels between 50–59%.

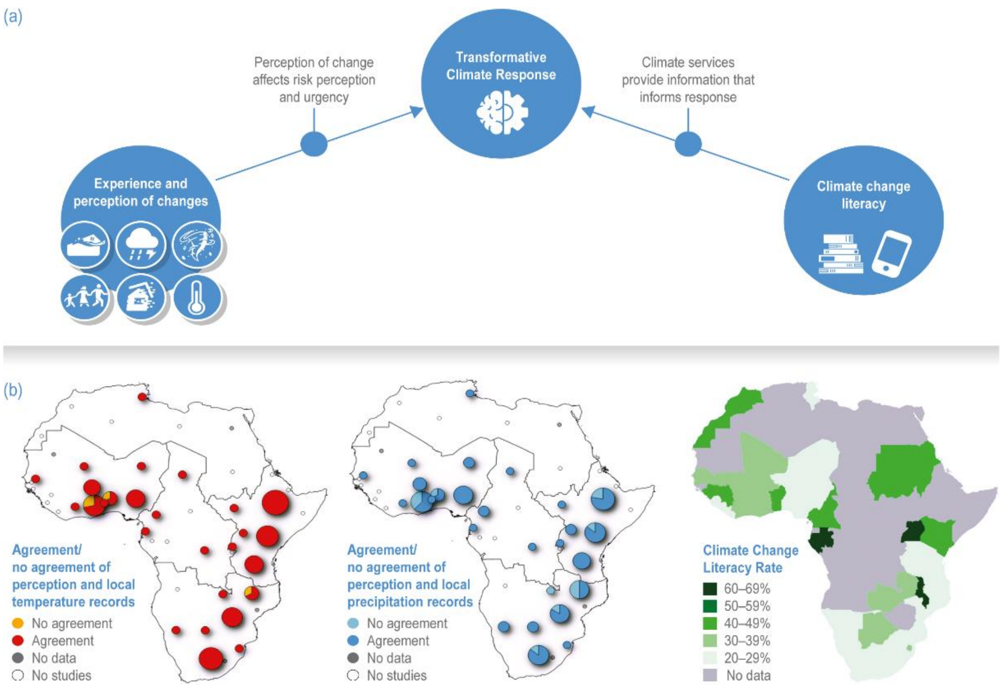

Figure 6: Climate Change Literacy in Africa
Source: IPCC, 2022

All this indicates that knowledge on climate change in Africa is still very low, which probably also contributes to the low adaptive capacity of farmers to climate change.

4. Conclusions and Recommendations

This paper has shown that *ndiwa* farmers have moderate adaptive capacity with a total score of adaptive capacity indicators of 41.6%, while *chamazi* farmers have low adaptive capacity with a total score of adaptive capacity indicators of 23.6%. The difference in adaptive capacity between *ndiwa* and *chamazi* farmers were caused by large disparities in financial, information and physical resources. In general, both *ndiwa* and *chamazi* farmers are likely to adapt to climate change despite low levels of adaptive capacity to survive. However, *ndiwa* farmers, who have higher assets standing, are able to adapt better than *chamazi* farmers because they can employ more adaptation strategies. According to Siders (2019), farmers with high adaptive capacity respond more effectively to climate risks by shifting from one adaptation strategy to another, while farmers with low adaptive capacity either respond only to risks that affect them most; and/or employ the cheapest adaptation measures due to the lack of resources, which in turn increase their vulnerability to climate change risks.

This paper recommends that the adaptive capacity of *ndiwa* and *chamazi* farmers be improved for them to employ adaptation measures and utilize available opportunities to transform from low to high food production techniques. This can be achieved by local government and central government authorities increasing their financial support to farmers' organizations and groups through soft loans. Also, district agricultural irrigation and cooperative units should construct and/or improve irrigation infrastructures—such as irrigation canals and water storage facilities—to enable farmers adapt to climate change more effectively. Similarly, meteorological stations should ensure that climate and weather information is accessible to all farmers.

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