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Agricultural Innovations and Adaptations to Climate Change in the Northern Cameroon Region

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Abstract: Climate disruption has serious impact on the entire agricultural production system at global scale. Research and development efforts as well as innovations may be necessary to offset the negative impact of climate change. Adaptation to climate change has remained a major socio-ecological issue in the Northern Region of Cameroon for three decades. Several agricultural innovations have been promoted in this region by international organizations and NGO, within the framework of different projects and programs, with a strong potential for adaptation to climate change. However, little is still known about agricultural innovations that have evolved over time in response to climatic factors. Therefore, research aiming at identifying adaptation strategies and practices at the local level is still limited. Also, rural communities and households do not always have access to these agricultural innovations because of lack of efficient innovation support service for agriculture. Through surveys and focus group discussions carried out in several villages in the Northern Cameroon Region, this study provides empirical data on emerging agricultural innovations in contrasting socio-economic, agricultural and ecological contexts. The study demonstrated that the process of adaptation at the village level using agricultural innovations is the result of various forms of support provided by a diversity of actors. However, heads of household (83%) are more involved in innovative initiatives to the detriment of other social strata, resulting in an imbalance in access and proximity to agricultural innovations. Also, support for agricultural innovations is segmented over time and weakens the sustainable transformation of adaptation due to the lack of coordination and the very low visibility of permanent structures dedicated to supporting agricultural innovations.

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1. Introduction and Background of the Study

The concept of adaptation to climate change refers to actions that contribute to reduce vulnerability to current or expected effects of climate change, such as climate extremes and risks. Adaptation is a process of adjustment of natural and human systems to an observed or anticipated climatic stimulus, to these effects and impacts with a view of limiting or eliminating potential damage or taking advantage of the opportunities created by climate change or variability [1]. Adaptation is considered like a set of changes in the procedures, practices, and structures of smallholder agriculture, aiming at limiting the actual or potential damage caused by climate change [2]. Seen from the perspective of climate change, adaptation would be closely linked to innovation, because, innovation can be understood either as a construction of the mind, or as a change [3]. Considering the significant ecological challenges of the study area, especially those linked to the impacts of climate change (the deterioration of production potential, reduction in median agricultural yields of 2% per

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decade [4], several authors have recommended agricultural innovations as a means of fighting against climate change [5–9]. In this view, several innovations have been introduced and implemented in the Northern Cameroon region with strong adaptation potential. These innovations are seen as adaptation measures implemented at the local level, for the use and need of rural communities. They include the planting of climate sensitive crop varieties and more drought-resistant trees; the practice of regenerative or conservation agriculture; the improvement of water storage and use; the implementation of agroforestry practices against extreme weather events such as floods and heat waves. However, these local responses in terms of agricultural innovations do not allow for lasting change.

Within the literature, local responses to the impacts of climate change have been analyzed by classifying them as "incremental", because they refer to minor modifications to existing practices and knowledge [10–12]. At the scale of change and current climate variability, transformational responses are increasingly necessary to avoid the pitfalls induced by extreme climatic hazards and situation of maladaptation [13,14]. Maladaptation is considered as a change in natural or human systems that leads to increasing vulnerability instead of reducing it [1]. Such a situation has been observed in the North Region of Cameroon, where vulnerability is increasing due to a low contribution of innovations available in the region. This maladaptation problem justifies this paper which aims at questioning to what extent agricultural innovations could truly contribute to adaptation to climate change? What would be the determinants that are missing from existing agricultural innovations to enable sustainable change in adaptation to climate change? The objective of the study is to analyze the agricultural innovations that have emerged and the determinants of their contributions to transform adaptation with an emphasis on systemic theories and approaches. Such an objective could allow us to move from incremental adaptation i.e. successive adjustments to deeper systemic and transformational adaptation [8,12,15–17]. Specifically, on the one hand, we would characterize the adapted agricultural innovations that have been promoted by showing their contribution to climate adaptation. And on the other hand, we will analyze the determinants of an effective and sustainable transformation of adaptation to climate change.

Finally the study contributes to achieving the objective of the agricultural sector in Cameroon, that of developing agriculture resilient to climate change and improving the adaptation capacities of farmers [18].

2. Study Analysis Framework

The present study is structured around two main concepts, namely agricultural innovation and transformative adaptation. Agricultural innovation is at the heart of the adaptation analysis, and it requires multi-actor approaches [19,20]. The multiple stakeholder approach is configured around three main analysis scales, notably the micro or local scale concerned by the beneficiaries i.e. farmer organizations or local communities [21], directly affected by climate change and variability. The medium or meso scale is made up of those who provide support to beneficiaries through their multiple interventions. These are indirectly impacted by climate variation. The macro or regional scale consists of the key actors who have the capacity to instigate change. This is the political level characterized by negotiations and advocacy to encourage adaptation with a view of reducing risks and the vulnerability of populations [22]. Innovation is at the heart of climate adaptation, and this is why some authors [23] consider innovation as adaptation and adaptation as innovation. Innovation therefore becomes essential to intensify adaptation to climate change. Hall [24,25] showed that research on agricultural innovation needs to rely increasingly on a participatory approach and include more actors (public and private sector and NGOs) if they wish to succeed socially and economically, instead of just looking at farmers and rural households. In Benin, many authors [26] have pointed out that the involvement of new actors with knowledge and skills in agricultural innovations is likely to boost adaptation to climate change. This requires considering the multi-actor or multi-stakeholder dimension in the innovation process. Innovation therefore becomes a product of a multi-actor process. These multiple actors provide services in support of innovations for the transformation of adaptation with a view of a transition towards transformative resilience.

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The concept of transformation provide insurance for a sustainable and bright future. Transformative [7] and transition [27] concepts used in this study suggest a more fundamental change. There were also used by IPCC in their fourth and fifth assessment reports [4]. In view of the above, the present study is not limited to examining the incremental adaptation implemented to mitigate the effects of climate change. It also involves moving towards systemic adaptation centered on multi-actor approaches as presented above. The same is true for transformational adaptation which remains the ideal means to build true community resilience [14].

3. Materials and Methods

3.1. *Study Area*

The study was carried out in the Northern administrative region of Cameroon (Figure 1), more precisely in the three intervention sites of the ReSI-NoC project to strengthen the innovation system in these dry territories. This project is structured around agrosylvopastoral innovation support in the Northern Cameroon Region. The project operates in three of the four administrative Divisions of the North region, namely: Benue, Faro and Mayo-Rey. In these three divisions, the project has demarcated thematic areas for its interventions. These include the South of Garoua metropolis. It is characterized by a high risk for resource degradation.

The second thematic zone is that in the immediate vicinity of protected areas. This Northern hold three national parks and 28 hunting zones known as Cynegetic interest zones (CIZ). These are areas experiencing regular tensions and conflicts linked to the access to land and natural resources. The last thematic zone of the project is the pioneer front of cotton and food crop production. It is an area in which there is a significant tendency to clear natural vegetation (shrub and tree savanna) to establish new agro pastoral farms. All the villages surveyed are in these three thematic zones as shown by Figure 1.

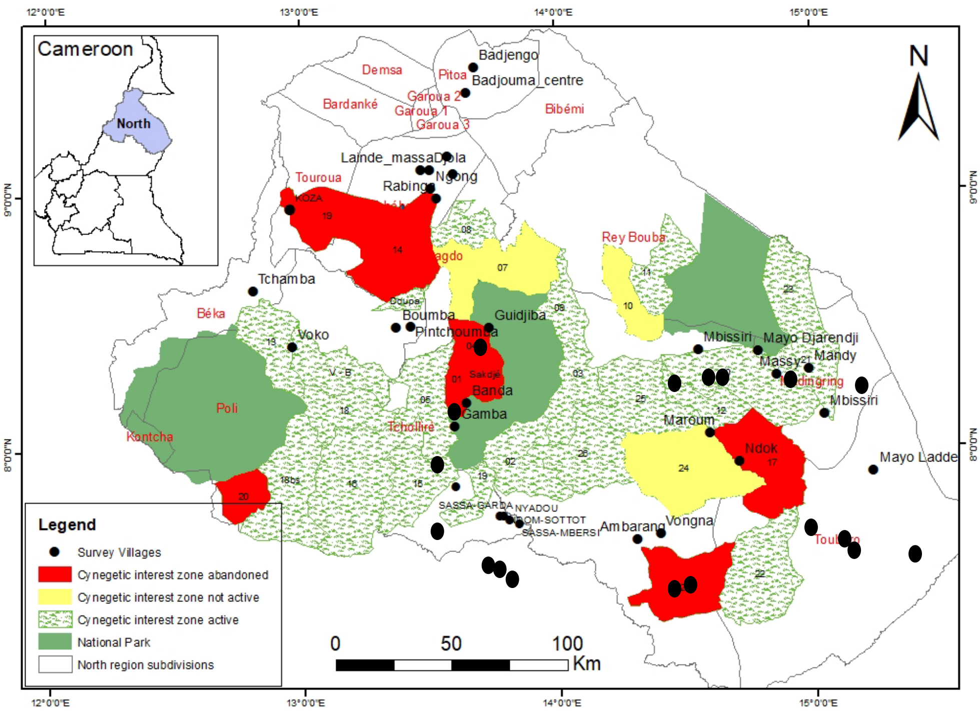

Figure 1. Location map of the study area.

According to the National Determined Contribution [28], the study area is located in the Sudano-Sahelian agroecological zone (North Cameroon Region). The climate is dry with 6-7 months of rainy season against 5-6 months for the dry season (Figure 2). Touboro and Tcholliré locations show a general increase in temperature starting from January, peaking around March-April, and then

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gradually decreasing. The temperature ranges approximately from 24°C to 30°C throughout the year. Garoua and Poli similarly to Touboro and Tcholliré, also experience an increase in temperature starting from January, peaking around April, with a sharper peak and slightly higher temperatures, sometimes exceeding 35°C. The temperature then decreases as the months progress. Touboro and Tcholliré locations show rainfall starting to increase significantly from May, peaking in August, and then sharply declining by October, indicating a clear wet season from May to September/October. Garoua and Poli rainfall patterns in these areas also start to increase from May, with a peak rainfall in July-September. The transition from the dry to wet season is quite abrupt, similar to Touboro and Tcholliré, with a sharp drop in rainfall as the year ends (Figure 2).

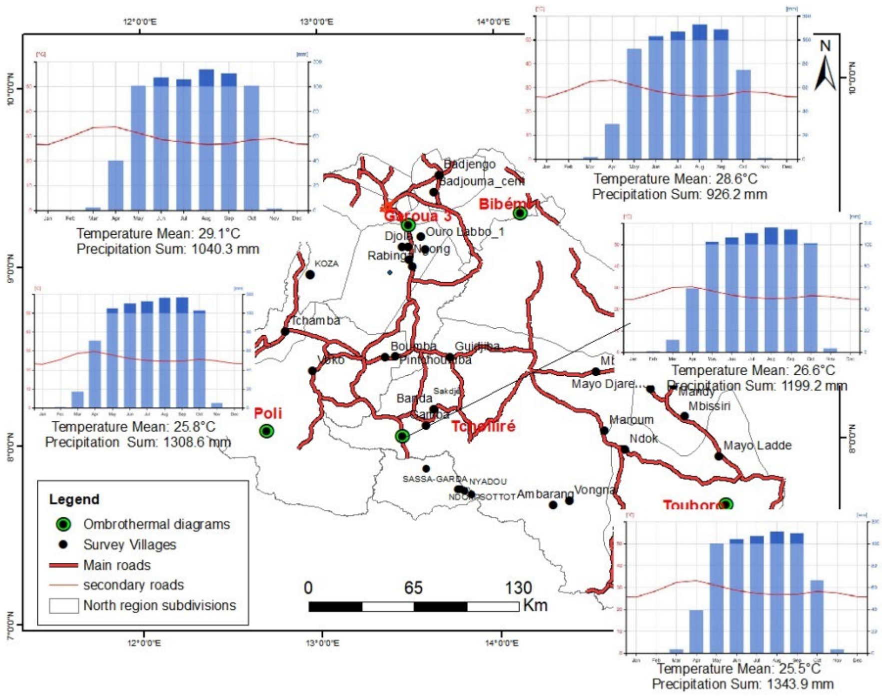

Figure 2. Climate regime of the North Cameroon region.

The region will experience an estimated temperature increase of +0.7°C by 2025; +1.2°C in 2035; +2.5°C in 2055; +3.6° C in 2075 and +4.8° C in 2100. Concerning precipitation, the scenarios generally predict a drier climate in this Sudano-Sahelian zone, with a decrease in rainfall of -2 to 0% at the end of the year. Projection in 2025-2035 show an increase of 1 to 10% in 2075 and 1 to 5% in 2100 (Table 1) with a concentration of rain in space and time [29,30]. Specifically, the study area is subject to great sensitivity to rainfall variation [31]. Producers have identified several climatic hazards, including variation in the crop calendar (early cessation of rains), agricultural and meteorological drought, and floods. These unfavorable climatic conditions are managed with great difficulty by agro pastoral populations.

Table 1. Projections of climate parameters at different time horizons from 2021 to 2100.

Projected Climate parameters	Scenarios	Time horizons			
		2021-2040	2041-2060	2061-2080	2081-2100
Rainfall trend scenario in %	RCP 2.6	-2 to 1	0 to 1	0 to 5	1 to 2
	RCP 4.5	-2 to 0	-1 to 4	0 to 5	0 à 1
	RCP 8.5	-1 to 1	-1 to 3	5 to 10	2 to 5
Temperature trend scenario in °C	RCP 2.6	0.5 to 1	1 to 1.5	3.5 to 4	4 to 4.5
	RCP 4.5	0.7 to 1	1.5 to 2	4 to 4.5	4.5 to 5.5
	RCP 8.5	1 to 1.5	2 to 2.5	4.5 to 5	5.5 to 6

Source: adapted from MINEPDED [30].

3.2. *Data Collection*

Through the methods of tracking innovations, notably the online documentary review of project and program reports, the multi-stakeholder workshops organized in the North Cameroon region and the semi-structured interviews, several agricultural innovations have been identified. The sites in which these innovations were identified constituted a study sample. The scale of these different innovation sites is that of the village because it is considered the privileged space for intervention by stakeholders, particularly those from the private sector, NGOs and cooperation organizations [21]. These actors participate in the implementation of agricultural innovations as well as their support. Part of the data for this study was collected in the framework of a baseline study carried out in 33 villages with 587 households. The choice of villages was guided by the innovation identified in the area. The collection of information was done by direct interview with the head of household, who could be either women (22.53%) or men (77.47%); migrants (41.20%) or natives (58.80%). In addition to these baseline villages, four other villages were surveyed as part of this study. In these villages, there was discussion on clarifying the content of the agricultural innovations observed. A drone and a camera were used for this purpose to image the content of agroforestry practices, the grassy and wooded strips, as well as the reaches. Interviews were conducted using interview guides. In addition, data was collected using two types of tools, including the household questionnaire and the village checklist. The first tool was denser in terms of volume of information and collected detailed parameters on agricultural production systems in households, while the second focused on data at the village level. The interviews were focused on identifying the main activities of the respondents (agriculture, livestock breeding and other types of activities), the manifestations and impacts of climate change, the identification of new agricultural practices in response to climate change, the performance of each of these innovative practices and the actors who produce and disseminate these technologies. In data collection, the Likert scale was used (satisfied, not satisfied) to assess the level of satisfaction with innovation support services.

3.3. *Data Analysis*

Once the data was collected, it was computed and formatted in the Excel 2016 spreadsheet and imported into SPSS software for statistical analyses. Two approaches were adopted for this purpose, namely content analysis and descriptive quantitative analysis. The descriptive quantitative analysis consisted of calculations of proportions (percentage) and means. Graphs and tables were constructed in order to visualize innovative practices adapted against climate change by households as well as the determinants of the contribution of agricultural innovation in sustainable responses to climate change [32]. The qualitative analysis was carried out using content analysis to extract the perceptions (meaning) of agricultural innovations by the respondents. Much attention was paid to the occurrences of meaning in the respondents' speeches and finally the data collected were analyzed in a combined manner. The presentation of the results is as follows: each category of analysis was supported by the discourses of the data embedded during the individual interviews. In doing so, we clarified the quantitative results with qualitative data. An analysis of the percentages of the Likert scale was applied to this study to assess the level of satisfaction with the services provided in support of innovations or adaptations.

4. Results

4.1. *Agricultural Innovations for Incremental Adaptation to Climate Change in the Northern Region of Cameroon*

At the beginning of the 1990s, the Northern Cameroon Region has benefited from the gradual appearance and development of climate-smart innovations. These innovations included the capacity to respond to current ecological challenges, particularly those linked to climate change through the triptych of adaptation, mitigation and productivity. This is the case of (1) conservation agriculture

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which allows the maintenance of soil humidity against drought; (2) rain erosion control techniques which limit the leaching of organic matter from the soil; (3) the conservation management of soil water at the level of watercourses which promotes the maintenance of the water table for a long time; and finally, (4) agroforestry practices which reduce deforestation and allow carbon storage. In the present research, we emphasize on the contribution of internal characteristics and potentialities of these climate-smart innovations on adaptation to climate change.

4.1.1. Conservation Agriculture Innovations

Conservation agriculture methods aims at maintaining soil fertility, or even improve it. In practice, it requires minimal soil disturbance, banning any clearing, ridging, plowing or heavy mechanical weeding; maintaining good soil cover through the conservation of plant residues on the soil surface without burning and crop rotation. Rotation as a practice involves the cultivation of seasonal speculations that may change over the years. It is based on the principle that plant soil nutrient and moisture requirements are not the same for all cultivated plants. The objective of rotation is to improve the physicochemical characteristics of the soil with a view to promoting water infiltration, reducing runoff as well as erosion and soil compaction, restoring soil fertility through organic matter intake. The types of rotation observed include cereals sown in the first year, legumes in the second year and cotton in the third year. In addition to rotation, producers also practice crop association on the same plots. It is the case for cereal + *bracharia* + grass or *Stylosanthes* combinations. Such a practice helps improving soil fertility by fixing nitrogen and facilitating soil aeration. In addition to these practices, we also observe composting which is a natural process of decomposition of organic matter by microorganisms under well-defined conditions.

Organic raw materials, such as crop residues, animal waste, are applied to soils as fertilizer. Its objective is to improve the quality of organic matter to make it more capable of improving the physicochemical and biological properties of the soil to improve their productivity. These are the practices most implemented by producers in addition to cultivation under plant cover, as shown in Figure 3. Cultivation under plant cover also allows soil moisture to be conserved and water evaporation to be reduced and the results is the increase of crop yields.

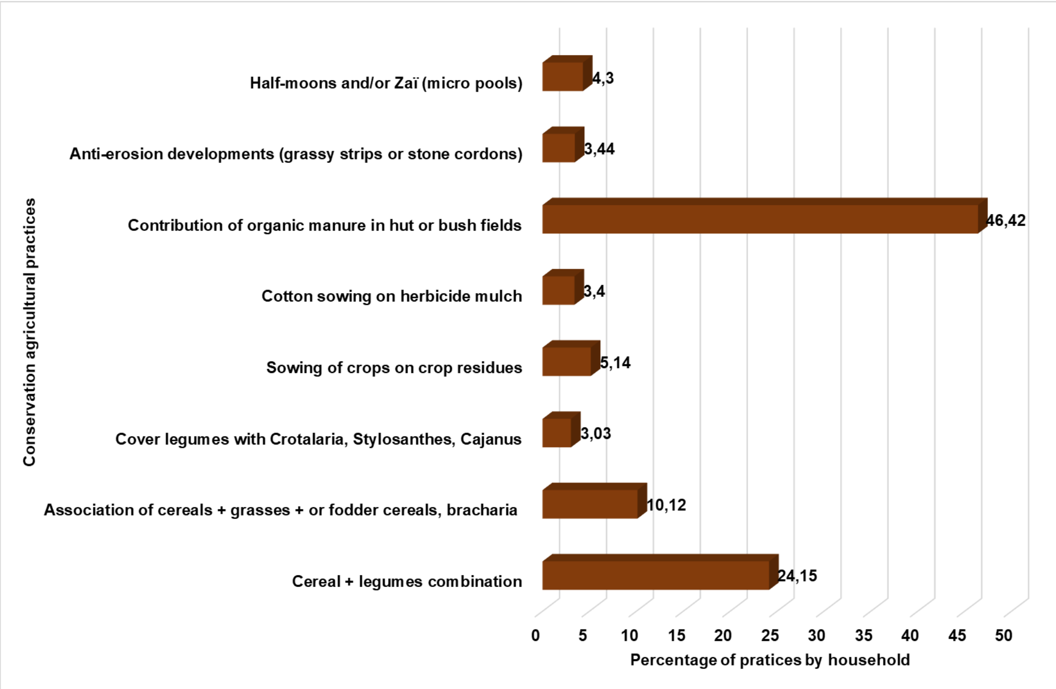

Figure 3. Use of conservation agriculture practices by households in ReSI-NoC project sites.

4.1.2. Innovations through Agroforestry Practices

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Following the great drought which struck the African Sahel countries including the northern part of Cameroon in the mid-1970s, Cameroon, like the other states of the sub-region located on the edge of the Sahara Desert, decided to implement activities combating desertification. With this challenge in mind, Cameroon, since the COP 21 in Paris, has seized all opportunities offered to take part to two main initiatives: the "Great Green Wall (GMV)" and "Restoration of Forest Landscapes in Africa (AFR100/Bonn Challenge)" [33].

Agroforestry practices are part of technical innovations introduced in the North Cameroon region since the great drought of the 1970s. They were implemented in collaboration with projects such as Green Sahel Operation (GSO) which consists of mass planting of trees to combat desertification. Also, to this aim, Cameroon creates the Provincial Committee for the Fight against Drought (CPLS) in 1975, relatively to the strategies taken at the African level. A part from this successful Green Sahel Operation, a sylvopastoral trial was set up near the Laf forest reserve in 1985, with a view to assess sustainable management techniques for degraded wooded savannas [34]. Furthermore, in the 1980s, the integration of trees into crops was examined using two approaches: (i) an evaluation of the existing situation, with an interest mainly focused on the traditional association of *Faidherbia albida* with different cultural practices; (ii) the testing of new systems including exotic species (fast-growing and/or multi-use) within crops according to supposedly more "rational" schemes (alley-cropping, windbreaks, hedges) [34]. In the 1990s, agroforestry, as a discipline, became part of the development practices [35].

Since 1990, among another actions were the fertility management and the place of trees in the village [36] as well as extensive attention devoted to evaluating the role of fallows based on *Acacia polyacantha* and *Cassia siamea* on the biogeochemical cycle of depleted ferruginous soils. Around 1996, the Agricultural Export Diversification Project (PDEA) made *Acacia Senegal* to become a tree of particular interest to produce Arabic gum. During the same period, the Peasant Development and Land Management program (DPGT) was set up and used a tree approach in rural areas through Research and Development. By relying on SODECOTON and benefiting of funding from the French Development Agency (AFD) and the Cooperation Assistance Fund (FAC), it was possible to launch important actions to promote the tree in agrarian systems. All these works were carried out in collaboration with the Institute of Agronomic Research for Development (IRAD). The themes of restoring fertility and combating erosion dear to the DPGT were only weakly taken up by farmers [37]. During the same period, IRAD benefited from financial and scientific support from the Regional Center for Applied Research for the Development of the Savannas of Central Africa (PRASAC). PRASAC came to reinforce the difficulties of DPGT by launching comparative on-farm experiments on the management of tree resources in combination with agriculture. In the 2000s, the Water, Soil and Tree (ESA) project was launched to support the testing of different agroforestry systems. From the above, we deduct that afforestation is an adequate response to climate crises and the restoration of degraded areas.

To achieve this, several actors are involved through projects and programs. Stakeholder engagement in agroforestry activities is linked to the sustainability challenges dominated by the effects of climate change and deforestation/degradation. The northern region of Cameroon has a diversity of actors who provide diverse support to face the main environmental threats. These actors are from the public and private sectors, civil society and farmer organizations. Agroforestry appears to be an important innovation promoted by all stakeholders, including related techniques such as afforestation and improved cropping systems. Several agroforestry practices have been adopted by households interviewed in the ReSI-NoC baseline study as shown in Figure 4.

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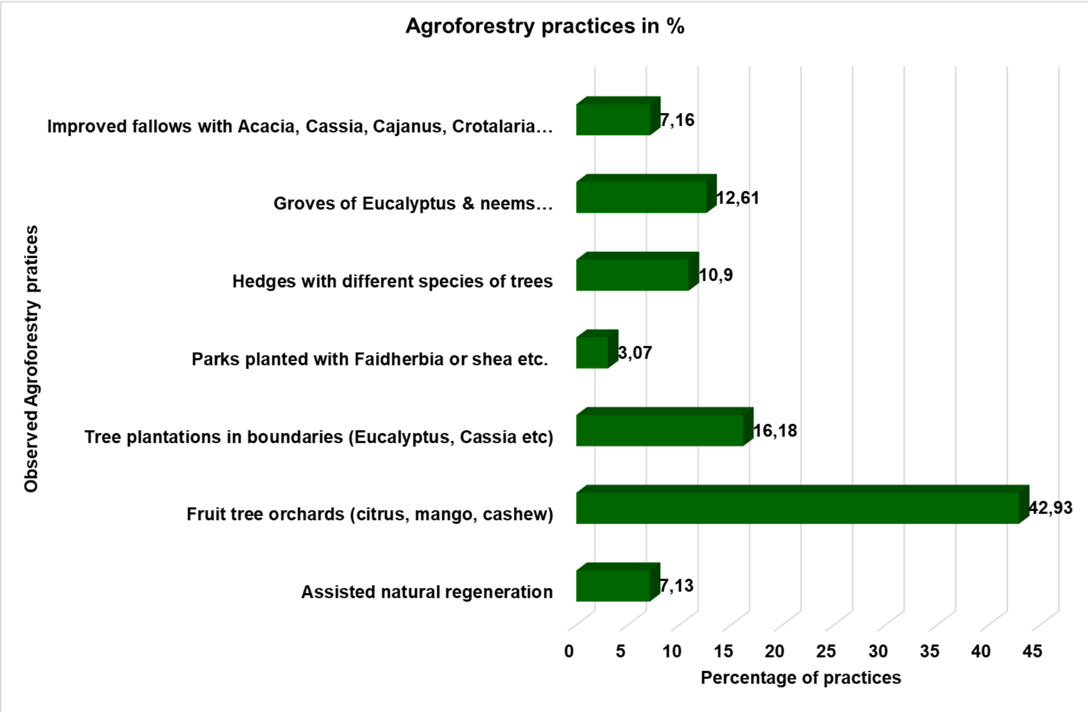

Figure 4. Agroforestry practices by households in the ReSI-NoC project sites.

Among agroforestry practices, those which contribute the most to the fight against climate change are hedgerows and wooded strips which surround agricultural plots (photo 1). They help to fight against violent winds and water erosion in crop fields.

Photo 1. Agricultural plot surrounded by hedges in Bamé. (Source: Tchuenga, February 2022).

Photo 1 shows the trees (*Azadirachta indica* or neem) around an agricultural plots. Neem trees constitute a fence and mark the boundaries of the plot. Inside the plot one can observe fruit trees like mango and cashew.

4.1.3. Water Conservation

Climate change has caused a significant shortage of surface water volume in Northern Cameroon. Groundwater levels were also impacted. The successive droughts of the 1972 and 1983 have impacted groundwater tables, resulting in difficulty to recharge and quickly drying up of wells. However, the availability of surface water in this Sudano-Sahelian region is also associated with strong seasonal and regional variability. Seasonal flowing rivers, called “Mayos”, are observed in the

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region. They are subject to a tropical Sahelian regime with sudden annual floods and very pronounced low water levels. The regime of watercourses is more linked to the duration of the dry season (07 months) and the length of the rainy season (05 months). The rivers' networks are numerous and vital for the populations. However, the extension of the dry season leads to the complete drying up of surface water with considerable impacts on the agro-pastoralism. It will therefore be necessary to invest in measures and technologies aimed at saving water for consumption adapted to the future. Thus, water saving measures are likely to become increasingly important when facing rapid population growth and prevailing drought. It is in this sense that the deadlock or the temporary micro dam retention (''*bief*'' in French) as an innovative technology has been promoted. It is a temporary water retention micro-dam intended to promote the infiltration of water into the ground. The word ''*bief*'' was introduced in the northern zone of Cameroon in 1984, to circumvent legislation on dams and for lack of finding an appropriate word designating both a temporary reservoir and aquifer recharge work [38].

The ''*biefs*'' are like micro-dams built with the following objectives, as summarized by Djombaye [38] : (i) stopping and gathering the water in one place to constitute a permanent or temporary surface water reserve; (ii) slowing down river water in one area to force it to infiltrate and replenish the water table. It is with this aim that the ''*biefs*'' or deadlocks were built in the region. There are several types of deadlocks including: masonry stone, concrete (Plate 1) and reinforced concrete, gabion, stone and earth and dry stone (blocked). It is a device built downstream of watercourses to limit the flow rate of the course. This device retains water from November at the end of the rainy season until April/May, which marks the end of the dry season (plate 1).

Plate 1. Masonry (A and B) in Ndock and stone wedged ''*biefs*'' (C) in Sabongari. (Source: Tchuenga, March 2022).

Thus, near these ''*biefs*'', water wells are easily built following the recharge of the water table. The device maintains water from November to April or even May (end of the dry season) for certain villages. The reaches have enabled the development of market gardening activities which did not previously exist (Results from the survey). Market gardening (tomatoes, onions, salad, off-season corn and vegetables) thus contributes to the diversification of income-generating activities for populations and the fight against food insecurity (Plate 2). In some villages, reach is used for

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household activities (Plate 2), because the effect of drought has contributed to the drying up of water points and wells.

Plate 2. Out-of-season vegetables and maize produced near the deadlocks of Douka Longo (Source: Tchuenga, March 2022).

Most of these practices are developed and disseminated by various actors among communities in the Northern region. According to them, these innovations have a strong potential to tackle several climate problems as shown in Table 2. Water conservation practices or access to water in the dry season in the region are numerous.

Table 2. Contributions of climate-smart innovations to adaptation.

Climate smart Innovations	Promoters of innovation	climate Problems adressed by innovation	Characteristics of innovation favourable to adaptation
Erosion control techniques (grassy and wooded strips)	SODECOTON	Water erosion contributing to the leaching of organic matter from crop plots	Blockage of runoff of organic matter by grasses and plants on plot boundaries
Conservation agriculture (crop association and rotation, organic manuring, sowing under plant cover).	SODECOTON / FODER, CARE International,	Drying of the soil and decline in fertility	Cultivation under plant cover maintains soil humidity favorable for plant growth. The crop association maintains soil fertility (corn and soya; soya and cowpea).
Agroforestry practices (fallow, assisted natural regeneration, reforestation associated with crops)	SODECOTON, GIZ, ABIOGeT, CERAF, PAECE CORP, MINFOF, MINEPDED	Erosion of crop plots, violent winds, drop in agricultural yield, extreme heat	Hedges constitute effective windbreaks which protect crops and generate carbon stocks. Ecosystem goods and services. Improved soil fertility
Water conservation (Zaï, Reach)	SODECOTON	Drought and early drying up of rivers	Recharging the water table and diversifying agricultural activities. Rehabilitation of the productivity of poor agricultural lands.

These agricultural innovations have developed technical skills and technical adaptation capacities in the households that use them. Almost 35.50% of households are satisfied with these technical innovations. However, despite all this progress, results from the baseline study show that 55% of women and 50% of men still struggle to easily manage climatic shocks and adversities.

Conservation agriculture, agroforestry, and water conservation are integral components of Climate-Smart Agriculture (CSA), which aims to increase agricultural productivity sustainably, enhance resilience to climate change, and reduce greenhouse gas emissions. These innovations have

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significant implications for adaptation, mitigation, and productivity within the framework of climate-smart agriculture (Table 3). Overall, integrating conservation agriculture, agroforestry, and water conservation into climate-smart agriculture creates more sustainable and resilient agricultural systems, helping farmers adapting to climate change while contributing to environmental conservation. Implementing these practices requires support from policies, research, and education to ensure that farmers have the knowledge and resources to adopt and benefit from climate-smart agriculture. Consequently, these practices can lead to more sustainable and resilient agricultural systems, contributing to food security and environmental sustainability in the face of climate change.

Table 3. Agricultural innovations practices against the pillars of CSA.

Climate smart agriculture	Conservation Agriculture	Agroforestry	Water Conservation
Adaptation	3	2	3
Mitigation	1	3	2
Productivity	3	3	3

1 less contribute, 2 contribute significantly 3 contributes more significantly.

However, beyond the availability of agricultural innovations, many households face difficulties in adapting to climate change. Which means that the presence and use of agricultural innovation is not enough to transform adaptation.

4.2. *Weaknesses of the Effectiveness of Agricultural Innovations in the Transformation of Adaptation to Climate Change*

Two parameters are essential for more effective adaptation to climatic shocks i.e. the level of household participation in innovative initiatives and the support for the agricultural innovations implemented.

4.2.1. Household Participation in Innovative Initiatives

The term participation means the active involvement of a wide range of households in the adaptation or innovation process implemented by the leaders of innovation projects in the region. Participation is a factor of appropriation, integration and dissemination of knowledge. Agricultural innovations are the result of collective construction. This is why the analysis of the participation of communities (households) in innovative initiatives is crucial. Despite the efforts made by organizations that support agricultural innovations in villages, approximately 62% of households in the study area are not informed of the existence of activities related to agricultural innovation. In addition, it is generally the heads of households (83.10% men) who are increasingly involved in the process of implementing and testing innovations. In terms of women's participation, only 38% are taking part. Also, 16.90% of young girls and 26.76% of young boys participate in activities related to agricultural innovations. These statistics reflect the unequal participation in innovative initiatives by gender. Also, it reflects limited access to information in adaptation strategies or even proximity to information. Poor access to information is one of the causes of maladaptive situations, hence increasing the vulnerability of households to climatic extremes.

Then, disparity exists in the choice of beneficiaries of innovative interventions by the different types of actors operating of the area (Figure 5). The focus put on the head of the family does not guarantee the transfer of information about innovations to other members of the family or the community. This contributes to weakening the flow of information within the community. Hence, the need to bring together all members of the household around initiatives to hope for a higher rate of adoption. Also, within the village, the number of households must be very representative of the community. The single choice of a leader or head of household presents a lot of risks in the dissemination of information related to innovations. The lack of participation of some households is explained by the non-compliance with the criteria set by the promoters to benefit from their

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interventions, little interest on the part of the beneficiaries, the lack of time and insufficient financial means. In addition to these constraints, we add more general factors such as poverty, low level of literacy, cultural taboos, problems of communication and awareness among populations.

Finally, in the participation process, a diversity of actors is involved, because innovation is a social construction (group, community, association, NGO, etc.) and not an individual construction. There is a diversity of organizations which are involved in the promotion of innovative initiatives. They belong to different categories, as shown in Figure 5. Thirty eight percent (38%) of the actors belong to the public sector while 34% fall in the parapublic category. They are followed by international and national NGOs (10% and 8% respectively). We also notice the presence of cooperation agencies (6%) and producer organizations (4%).

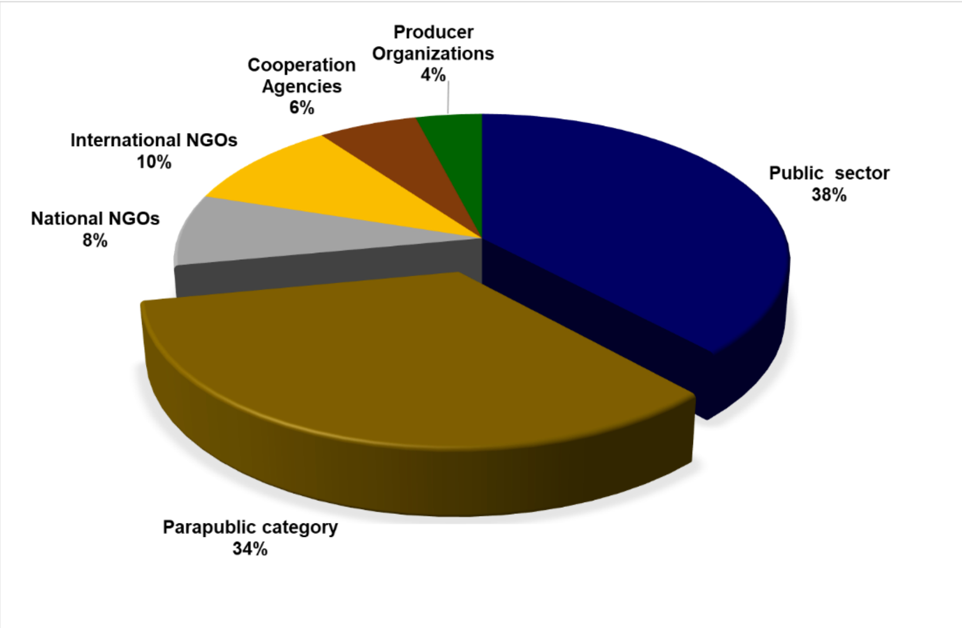

Figure 5. Actors disseminating innovative initiatives.

These innovation project leaders are involved in different phases of the adaptation or innovation process, including the initiation and implementation (experimentation) phases of initiatives. To this effect, different types of support are offered (Table 4).

4.2.2. Support for Agricultural Innovations

Since the 1990s, projects and programs have remained the main mechanisms for supporting agricultural innovations in the Northern Cameroon region. They offer several forms of support to innovations, for example awareness raising, training, local supervision, provision of various inputs, provision of materials and equipment, access to credits and financing of micro-projects (Table 4). Regarding these services, 80.52% of households in the baseline study were satisfied with these services while 19.48% were not satisfied.

Table 4. Forms of support for agricultural innovations by stakeholders.

	Intervention approach	**Total**

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	Awareness raising	Training	Local supervision	Donation of inputs	Donation of equipment	Access to credit	Financing of micro-projects	
Number of households	191	140	130	41	18	74	11	232
Percentage	82.33	60.34	56.03	17.67	7.76	31.09	4.74	

This Table 4 illustrates the number of households following each intervention approach and calculated by percentage. This makes it possible to highlight the weight of each intervention approach and the level of participant used by the actors among a total of 232 interview participants.

Approaches based on training, awareness-raising, local supervision and access to credit are considered to be the most used by innovation projects (Table 4). It is worth mentioning that this type of support has replaced the role that was previously ensured by government structures like IRAD and MINADER (Ministry of Agriculture and Rural Development). These two structures are part of the pillars of the national agricultural research and innovation system. However, the agricultural innovation support mechanisms offered is unsustainable and inefficient. The short lifespan of projects and programs supporting agricultural innovations segments the support for innovation or adaptation over time. As soon as an actor finishes its intervention, a new actor arrives and often intervenes in the same region introducing the same innovations with different approaches. This will lead to confusion among farmers and livestock owners who do not know whom to contact for information. Furthermore, one can observe duplication of interventions and a geographical imbalance in the provision of services in support of agricultural innovations. Hence the need for coordination within the areas of intervention.

5. Discussion

The present work highlights two major results. The first one suggest that agricultural innovations implemented in the region have appropriate capacities to respond to climate change. However, these agricultural innovations alone are not enough to transform adaptation to build true community resilience. Secondly, the obstacles hindering the effective contribution of agricultural innovations to climate change adaptation in the region have been identified. First, there is a dominance of men (head of household) interacting with initiatives to the detriment of other social groups. This overrepresentation does not always guarantee the transmission of acquired knowledge to other members of the family. Then, support for agricultural innovation through support services tend to focus more primarily on technical aspects. In this section, we discuss these two results by comparing them to general results from the climate change adaptation literature.

5.1. *Implications of Agricultural Innovations in Incremental Adaptation to the Impacts of Climate Change in the Northern Cameroon Region*

Three innovations for adaptation to climate change were analyzed on the contribution of their internal characteristics to responding to climatic hazards. These include conservation agriculture, water erosion control techniques, water conservation in rivers and agroforestry practices. Agricultural innovations have proven promising for adaptation in five West African countries including Ghana, Mali, Niger, Senegal and Burkina Faso. The same agricultural innovations were analyzed in the context of climate change and variability in Ghana by Parthey et al. [5] with an emphasis on climate smart agriculture. In the same sense, Brou [39] demonstrated in the case of climate uncertainties that, agricultural innovations constitute a strategy to improve adaptation for

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better agricultural productivity. Tchuenga et al. [40] highlight conservation agriculture as an agroecological practice allowing adaptation to climate variability in Bangangté in the Western Cameroon region. These included crop association practices which are cultivation practices used since the dawn of agriculture [41]. But, in the last 10 years, they have gradually experienced real developments due to the concerns of farmers who seek to combine the efficiency of production factors, the fight against climate change and the preservation of biodiversity. The present study marks the first transformative phase of adaptation which consists of stopping "maladaptation" to the future impacts of climate change. It was based on an evaluation of agricultural innovations in their contributions to adaptation which, instead of reducing vulnerability, reinforces it in the face of the effects of climate change. However, there are some bottlenecks which constrain the agricultural innovations in strengthening climate resilience of producers in Northern Cameroon.

5.2. Existing Blockages in the Contribution of Agricultural Innovations to Climate Change

To move from situations of incremental adaptation to transformational adaptation, it is imperative that (i) communities participate strongly in the processes of innovation or adaptation and (ii) permanent structures supporting agricultural innovations provide adequate services, so that adaptation is sustainable and effective. The need to strenghten community participation in climate change adaptation projects has been highlighted in the literature by several authors [42–45]. However, in our study area, we observed inadequate integration of all social components at the local rural communities in innovative initiatives. This fact invites us to further explore the way in which stakeholders in the innovation or adaptation process (project managers and donor organizations) conceptualize and idealize community participation. Nevertheless, in climate adaptation studies, such studies have not yet been conducted. In the North of Cameroon, support services mostly provided in the context of climate change, are awareness-raising, capacity building, knowledge exchange, technical support and improved access to resources. These services also appear in the literature on innovation support services [45,47,48]. Further, the World Meteorological Organization (WMO) global climate services framework has recognized the importance of integrating capacity building as a climate service. Some authors [49] have also recognized that the advisory service is crucial for environmental issues, particularly those linked to climate change, because access to information can increase the adaptive capacity of agricultural producers [50]. In terms of sustainability, it is necessary to integrate new services, notably coaching and stimulating creativity [51]. These new services have the transformative capacity to adapt to climate change, but are rarely provided.

The study demonstrate weakness of permanent structures in supporting agricultural innovations. And yet, literature has shown that organizations, particularly local ones, participate in the dissemination and support of agricultural innovations [52–54]. Nevertheless, it will be necessary to develop the functional capacities (coordination) of these organizations to enable them to contribute more effectively to sustainable change in adaptation to climate change.

6. Conclusion

Climate disruption has serious impact on the entire agricultural production system at global scale. Research and development efforts as well as innovations may be necessary to offset the negative impact of climate change. Adaptation to climate change has remained a major socio-ecological issue in the Northern Region of Cameroon for three decades. Several agricultural innovations have been promoted in this region by International organizations and NGO, within the framework of different projects and programs, with a strong potential for adaptation to climate change. However, little is still known about agricultural innovations that have evolved over time in response to climatic factors. The objective of the paper was to determine to what extent adaptations based on agricultural innovations can promote sustainable change (transformation) in the context of climate change in the North region of Cameroon. Thus, questionnaire surveys to households and analysis of the content of these questionnaires were carried out. The results show that agricultural innovations introduced in the region induce non-sustainable changes in adaptation because they are implemented and accompanied by projects and programs which are one-off and not permanent. Also, the expected changes at the household level are weakened by the disparity in the choice of participants in innovative initiatives by the actors. Our results shows that there are two determinants leading to a transformative adaptation such as participation of local community and farmers organizations to the promotion or emergence of innovations and the permanent support to innovation for the long-term sustainability and change in adaptation strategies. However, little is known about agricultural innovations for climate change adaptation because of the weak participation of local community. Agricultural innovations are implemented and accompanied by projects and programs which are time-bound and not permanent. Also, the expected changes at the household level are weakened by the disparity in the choice of participants in innovative initiatives and temporary support by the actors. Heads of households overrepresented (83.10%) than other social components (women, young girls and boys). The fact that the head of the household is the main contact for the initiatives is a hindrance to the dissemination of knowledge, raising the necessity to introduce specific activities for the other members. The focus put on the head of the family does not guarantee the transfer of information about innovations to other members of the family or the community. This contributes to weakening the flow of information within the community. Hence the need to bring together all members of the household around initiatives to hope for a higher rate of adoption i.e the sustainability of the action is not always guaranteed by this approach. Introduction of any kind of innovation within a community, need an inclusive approach to avoid the marginalization of a certain categories of people. In addition, the temporary support is incomplete because, it is mostly based on training, awareness-raising, local supervision and access to credit. It is therefore necessary to offer a complete package of support that also emphasizes post-training, follow-up and coaching, and facilitates access to inputs, small equipment and credit. This research is part of the scientific field on climate change adaptation which nowadays requires systemic approaches, and which calls for multidisciplinary reflection. Few studies in Cameroon have highlighted the implication of adjustments induced by agricultural innovations in the study of adaptation to climate change. The present paper contributes to the broadening of the research in the field. Even more, it is no longer a question of citing reactive and planned adaptation measures in response to climate change, but of examining the transition mechanisms to adjustments towards the analysis of transformational processes. By following this logic, the study made it possible to detect some existing fragilities in this transition process in the North Cameroon region. This line of inquiry must be further investigated by adaptation researchers and professionals to contribute to the sustainable resilience of Cameroon's agricultural sector at local, regional and national scales.

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Acronyms

ABIOGeT: Actions pour la Biodiversité et Gestion des terroirs
AFD : Agence Française de Développement - French Development Agency
AFR: African Forest restoration
CARE International: Cooperative for Assistance and Relief Everywhere Inc.
CERAF: Centre des Ressources Agroforestières
CIFOR: Centre for International Forestry Research
CIRAD: Centre de Coopération Internationale en Recherche Agronomique pour le Développement

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CIZ: Cynegetic interest zones
COP: Conference of the Parties
DPGT : Développement Paysannal et Gestion des Terroirs - Peasant Development and Land Management
ESA: Eau, sol et arbre - Water, Soil and Tree
FAO: Food and Agriculture Organization
FAC : Fonds d'Aide à la Coopération – Aids Cooperation Fund
FODER: Fonds pour le Développement Rural : Rural Development Fund
GMV : Grande Muraille verte - Great Green Wall
GIZ: Deutsche *Gesellschaft für Internationale Zusammenarbeit* (German technical Cooperation)
GSO: Green Sahel Operation
ICRAF: International Centre for Research in Agroforestry
IRAD: Institut de Recherches Agronomiques pour le Développement –Institute for Agricultural Research and Development
MINADER : Ministère de l'Agriculture et du Développement Rural-Ministry of Agriculture and Rural Development
MINFOF: Ministère des Forêts et de la Faune – Ministry of Forestry and Wildlife
MINEPAT : Ministère de l'économie, de la planification et de l'aménagement du territoire
MINEPDED : Ministère de l'Environnement, de la Protection de la Nature et du Développement durable-Ministry of Environment, nature protection and Sustainable Development
NGO : Non-Governmental Organization
PDEA : Projet de Diversification des Exportations Agricoles - Agricultural Export Diversification Project
CPLS : Comité Provincial de Lutte contre la Sécheresse - Provincial Committee for the Fight against Drought
PRASAC Pôle régional de Recherche Appliquée au développement des Savanes d'Afrique centrale -Regional Center for Applied Research for the Development of the Savannas of Central Africa
ReSI-NoC : Renforcement des systèmes d'innovation dans le Nord Cameroun
SODECOTON : Société de Développement du Coton –Cotton Development Corporation
SPSS: Statistical Package for Social Sciences
WMO: World Meteorological Organization

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