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Coping with climate variability and change in research for development targeting West Africa: Need for paradigm changes

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Abstract

Climate change and variability impact on agriculture in the West African Semi-Arid Tropics (WASAT). At present WASAT farmers are most concerned by climate variability which shows the greatest consequences towards the northern drier end of the region. Relative variability, number of existential droughts, species loss and variety turnover are highest there. This paper presents experiences made and approaches developed in the framework of a Research for Development (R4D) project aiming at preparing WASAT farmers to deal with climate constraints. It is argued that agro-phytodiversity management is a reasonable approach to deal with climate variability but that it needs better social organisation to conserve a sufficient number of crops and varieties. Optimised participation and empowerment of farmers in the R4D continuum leads to faster progress with respect to innovation testing, adaptation and sustainable adoption.

Keywords : agro-phytodiversity, farmer exchange visit, participatory research, scientific approach, varietal diversity.

Résumé

Adaptation à la variabilité et au changement climatique dans la recherche pour le développement visant l'Afrique de l'Ouest : la nécessité d'un changement de paradigmes

La variabilité et le changement climatique ont un impact sur l'agriculture dans la région tropicale semi-aride de l'Afrique de l'Ouest (WASAT). À l'heure actuelle les agriculteurs de cette région sont les plus concernés par la variabilité du climat qui a des conséquences importantes à l'extrémité nord, plus sèche, de cette zone. La variabilité relative, le nombre de sécheresses, la disparition des espèces et le changement des variétés sont courants. Cet article présente les expériences et les approches menées dans le cadre d'un projet de recherche pour le développement (R4D) visant à préparer les agriculteurs de la région à mieux faire face aux contraintes climatiques. Il est généralement admis que la gestion de l'agro-phytodiversité est une approche raisonnable pour faire face à la variabilité du climat, mais celle-ci a besoin d'une bonne organisation sociale pour mieux conserver un nombre suffisant de cultures et de variétés. La participation optimisée

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et l'autonomisation des agriculteurs dans le continuum du R4D conduisent à des progrès plus rapides en ce qui concerne les tests des innovations, et leurs adaptation et adoption durables.

Mots clés : agro-phytodiversité, approche scientifique, diversité variétale, recherche participative, visite d'échange des agriculteurs.

What should be the research focus in the West African Semi-Arid Tropics (WASAT) environment?

Approaching the agricultural reality in the semi-arid sub-Saharan Africa, the question arises what to prioritize in research: climate change or climate variability? In this context it seems necessary to define the difference between these two terms first. In fact – as have shown decades of interdisciplinary and applied research in special research programmes on agriculture in the tropics at the University of Hohenheim – proper definition of key terms should be one of the first communication steps in mixed teams.

We define climate change here as the significant change of climate variables (*i.e.* total rainfall, mean annual temperature) at multi-decadal time scale. In contrast, climate variability means under the seasonal conditions of the West African Semi-Arid Tropics (WASAT), the change of climate variables from year to year as it can be expressed by total differences between years, standard deviations or coefficients of variation of multi-annual measurements. With respect to farmers' reality, the temporal scale of climate change corresponds to strategic decisions, *i.e.* which farming system to choose, whereas climate variability corresponds to tactical decisions, *i.e.* which crop varieties to grow depending on the date of the rainy season onset. The more we orient towards the north in WASAT, the less choices we have with respect to strategic decisions, since biophysical conditions are such that we approach the limits of cropping itself and pearl millet (*Pennisetum glaucum L.*) and cowpea (*Vigna unguiculata*) dominate subsistence-oriented farming systems.

In this biophysical environment farmers recognise signs of climate change but never stated it as their most important problem. In subsistence-oriented systems, producing the minimum for the survival of the family is the primary goal, and risk aversion is usually very high (Brüntrup, 2000; Yusef and Bluffstone, 2007). Consequently, the question how to produce the requested minimum under the given seasonal conditions is in the centre of thoughts and rainfall amount and pattern play a crucial role here. The Sahel precipitation anomalies for the time frame from 1950 to 2011[1] show above average rainfall in the 1950s and 1960s of the last century and below average rainfall in the period between the beginning 1970s until the mid-1990s. Since then rainfall is heavily fluctuating around the long-term average; in other words, "there is no such thing as normal rainfall" in West Africa (Hulme, 2001; Haussmann *et al.*, 2012).

Dealing with changes in the WASAT cropping systems during the last decades, we need to be careful with respect to the real driving forces behind the changes stated by farmers (Mertz *et al.*, 2009). For example declining soil fertility is an often mentioned phenomenon. However, reasons behind declining soil fertility can be multiple. Taking wind erosion as one major process behind fertility decline as example, it can be related to climate effects, since drought conditions favour wind erosion. On the other hand we have to ask why wind erosion has become so important. And here population growth resulting in extended agricultural surfaces, as well as changing management practices (complete clearing of fallows, complete and repeated weeding) play a role. In addition, fertility decline can have other simpler causes like lack of appropriate fertilisation or crop rotation.

Based on these reflections, in the following discussion we take climate change as a fact but lay more emphasis on how farmers can adapt to climate variability, since adaptation under the given conditions is more important to farmers than mitigation of long term climate change. However, a better understanding of how to cope with current climate variability is also considered a prerequisite for adaptation to future climate change (Cooper *et al.*, 2008). In addition, we discuss how researchers can better support the development of farmer adaptation capabilities under their given complex environment, rather than focusing on climate variability alone, since climate variability is only one though important facet farmers have to consider on how to manage their farm households (fields, crops, varieties, labor, animals, etc.). Instead of trying to identify the extent to which climate variability is impacting on the farming systems, we take a holistic perspective and try to develop strategies that recognise climate variability as one condition farmers have to deal with in a more complex environment.

The following reflections are mainly based on experiences gathered in the framework of the CODE-WA R4D project (Community management of crop diversity to enhance resilience, yield stability and income generation in changing West African climates) funded between 2008 and 2011 by the German Federal Ministry for Economic Cooperation and Development[2].

Accepting variability and diversity as research paradigms

General reflections

Very often when agricultural research questions are developed, the intrinsic concept includes one solution to the stated problem (and if we dig deeper, this is often related to the way we develop our research hypotheses and analyse our results). This fact might be demonstrated by one single fertiliser recommendation per crop and country, as often found in the WASAT. We would like to challenge this approach, because from our view this "one solution rule", though easy to apply, e.g. by state extension services, is a major reason for non-adoption by farmers, since their environments are more variable and their reasoning is not univariate (see also Zingore *et al.*, 2007; Giller *et al.*, 2011).

Still today many scientific experiments are based on monocropping. However, if we look into subsistence farmers fields,

[1] http://jisao.washington.edu/data/sahel/

[2] http://codewa-icrisat.uni-hohenheim.de/Website/Welcome_to_the_CODE-WA_homepage.html

most of them show crop associations, which is often forced by decreasing surface available per farm (at present 1.6 hectare in Africa, von Braun, 2005) and serves at the same time as risk diversification strategy (Sheety *et al.*, 1987; Traore, 1998). Performance of a developed technology is often judged by scientists comparing the average performance of a treatment in contrast to a control. If the standard deviation of the treatment/new technology is greater than the one of the control, the technology might be rejected due to statistically non-significant differences, though under certain conditions, which are in most cases not further researched, the technology might be superior under specific farming conditions.

To give a hypothetical example, we test a low-input fertiliser technology on-farm in a certain region. Response is miscellaneous, differing from site to site with no significant mean difference in comparison to the control. Under normal conditions we now reject the H1 hypothesis concluding that the technology has no potential. However, if we had a closer look, we could have remarked that there is a spatial trend, the technology performing better with distance to the settlement and in women's fields. So a spatially and socially stratified analysis would have shown the technology advantage under specific conditions.

In another example, a phytosanitary treatment has shown its superiority to the control. Though potentially helpful, the technology is not adopted by subsistence farmers, which represent the dominant clientele. The reason is limited access to markets and limited investment potential. So here a gap appears between potential and farmers' realities. Given the limited financial resources for agricultural R4D work, we should concentrate on what has a realistic chance to be adopted by smallholder farmers. These measures need to show an impact in the short – or at least mid-term – otherwise there is little chance for adoption.

In a third example, a new "climate change adapted" short duration variety has been released. However, in the first year after release it fails and is rejected by farmers due to flowering during major rain events in an exceptional high rainfall year. This example shows that we need to take into account the risk management of subsistence farmers (risk avoidance, no total failure allowed) as well as an at least mid-term approach (three or more years) for testing a varieties advantages as well as disadvantages with respect to climate variability.

These are the reasons why single answer packages do not really offer a solution. Acknowledging the need for site-adapted solutions, more work under farmer conditions and with farmer contributions is mandatory in order to take the variability of the biophysical environment as well as the multi-facetted reasoning of farmers into account. On-farm testing has been reported essential to obtain a critical mass of representative testing environments and production-system-relevant responses (Weltzien and Christinck, 2008). In order to do so, we need to work in interdisciplinary teams and to appropriately sample the heterogeneity of our target environment (both biophysical and socio-economic contexts) and identify solutions for the individual "socio-ecological niches" as defined by Ojiem *et al.* (2007) if we search for impact. In order to achieve long-term sustainability of such activities, local people (*i.e.* farmer organisation representatives) should acquire capacities to identify new constraints and opportunities and to more independently perform adaptive experiments.

In the following, some variability/diversity aspects are highlighted by real world examples experienced during the CODE-WA project. The term diversity is used for nominal (e.g. varieties) and variability for interval type (e.g. rainfall amount) differences.

Biophysical environment

• Climate variability

For a farmer in the semi-arid tropics with a seasonal climate, the effective characteristics of a season count. Important questions in this respect include the following:

– When do the rains start? If they start late, the season will probably be shorter and a need for short duration (or photoperiod-sensitive) varieties emerges. In case of a late planting, temperature at germination during the establishment phase of the crop may be suboptimal which could reduce early crop vigour.

– Will there be any droughts and how long does the season last? Early droughts impact on crop establishment and may demand re-sowing, and consequently a sufficient seed stock. Terminal droughts especially those occurring during flowering and grain filling impact very negatively on grain yield and consequently on food security and available seed stock for the next year. The answer is drought-resistant varieties.

– Will there be extreme rainfall events and if yes when? Heavy rains falling during flowering might wash away the pollen and thus reduce grain yield. Heavy rains resulting in a longer-term flooding of a field can destroy a sensitive crop.

– How will the season affect appearance of pests and diseases?

These questions underline that a seasonal and site specific forecast would be advantageous for farmers. However, up to date this is not feasible for WASAT. Generally, predictions solely based on sea surface temperature (SST) failed so far (*i.e.* Tompkins *et al.*, 2012), leading to the conclusion that in the West African case with free air circulation over the continent, it might be necessary to include continental feedback mechanisms.

Having no forecast possibilities in sight, a tool called Agro-climatic Diagnostic Chart (ADC) was developed within the frame of the CODE-WA project which allows to classify seasonal variables based on comparison with historical climate data, namely probability distributions from wet years (1950s to 1960s of last century), dry years (1970s to 1980s), the current period (1991 onwards) and long-term averages (1951-2009). *Figure 1* exemplarily shows results for rainfall and growing period onset at the Sahelian site Serkin Haoussa in central-southern Niger and the Sudanian site Nobere in southern Burkina Faso.

The ADCs show that rainfall variation during the CODE-WA experimental period is higher at the drier Sahelian site, both in absolute and relative terms. At the Sahelian site rainfall in the first project year (2008) is congruent with long-term average, the second project year (2009) suffered from extreme moisture deficit, rainfall amount was lower than necessary for cropping, and the third year (2010) exceeded average rainfall by approximately 200 mm. On the other hand, the wetter Sudanian site experienced only average to above-average annual rainfall. However, farmers there stated that rainfall in years preceding the project was much lower with water wells partly falling dry.

Both sites show on average a delay in the onset as well as the end (not shown) of the rainy season compared to the long term average and even compared to the dry period, meaning for both sites a change in temporal rainfall pattern.

These aspects show that sites in WASAT differ with respect to climate variability, those at the drier northern end suffering more from climate variability. Consequently researchers need to respond with site-specific strategies in order to cover climate variability on-site. The observed climate variable behaviour

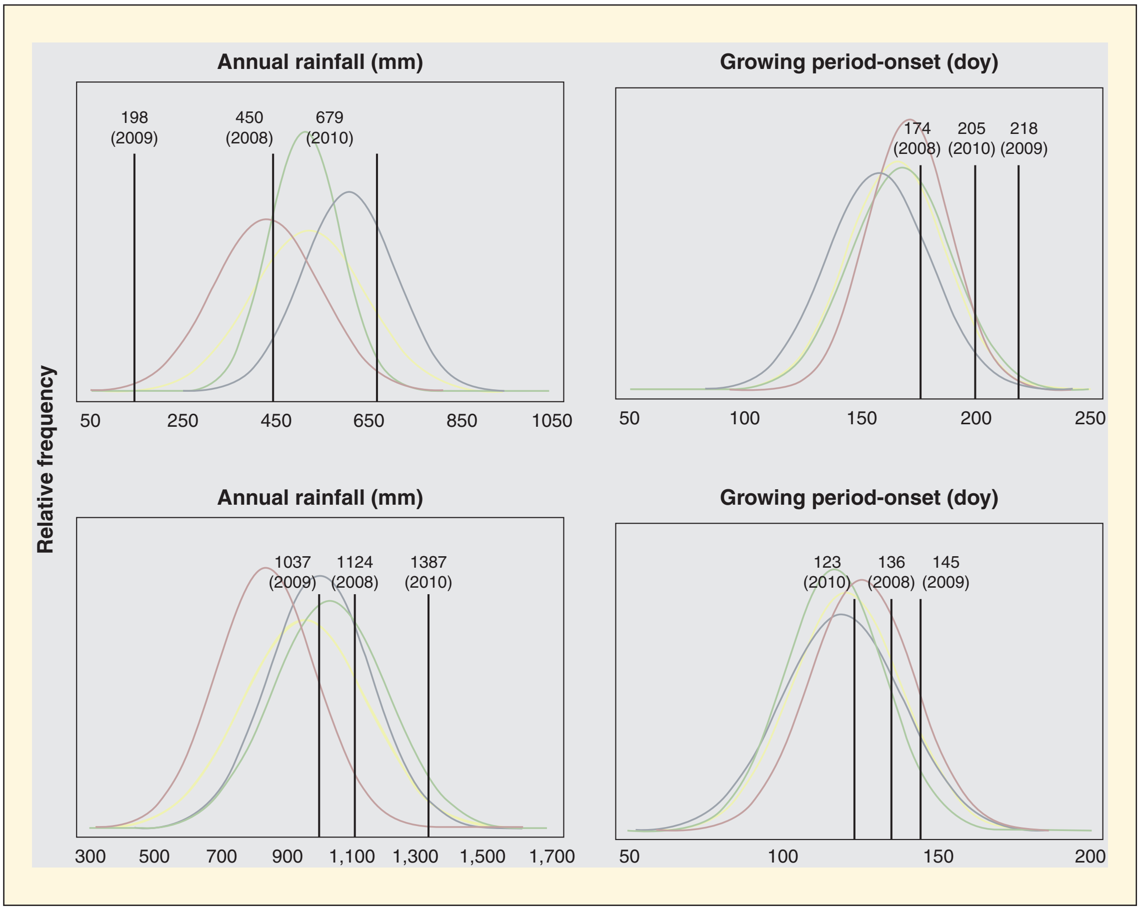

Figure 1. Agro-climatic diagnostic charts for a Sahelian site in Niger (upper) and a Sudanian site in Burkina Faso (lower) with variables occurring during the three central CODE-WA project years (2008-2010).

doy = Julian day; yellow line = long term reference period 1951 2009; green line = current reference period 1991-2009; red line = dry reference period 1971-1990; blue line = wet reference period 1951-1970.

also leads to the conclusion that concepts and technologies proposed to farmers need to be tested on a multi-annual time-scale in order to cover potential variability. Crop modelling may help testing specific scenarios, but the ultimate validation of technologies can only take place on-farm over years. This fact has consequences for funding strategies, which need to be more mid-term oriented. Otherwise impact will rarely be achieved.

The CODE-WA project made the error – based on the assumption that climate change leads in general to shorter crop growth periods – to propose to farmers absolute short-duration varieties. However, it turned out that at the wetter southern sites, *i.e.* pearl millet performance then suffered from high risk of pollen being washed of the panicles, since flowering fell into periods with high rainfall. But farmers adapted by experimenting with varying later sowing dates, a measure which helped to diversify risk and distribute work load.

It was also misleading to assume that crops in WASAT only suffer from drought conditions. At the southern sites with in general more loamy soils, on-farm experiments failed several times due to water stagnation at the surface following excess rainfall. Consequently breeding also needs to address traits neglected so far, like tolerance to lower soil temperature and temporal oxygen deficiency in early growth stages due to high water saturation after heavy rains. In conclusion it appears that at present both aspects – climate change (temporal shift of season) and variability (inter- and intraannual rainfall) – need to be considered to develop sound adaptation strategies for WASAT farmers, variability being the major concern for farmers.

• Soil variability

Testing of new technologies by research normally starts on-station for reasons of exactness and control. However, most station soils are known to be overfertilised and in consequence show non-representative responses. So especially if fertility aspects are concerned it might be wise to strengthen on-farm testing by researchers. Doing so, especially under the extremely sandy Sahelian conditions, another challenge appears: soil micro-variability, caused by differences in pre-clearing vegetation, micro-topographic differences and differences in preceding land use (Brouwer *et al.*, 1993; Herrmann *et al.*, 1994; Bürkert, 1995; Voortman, 2010). This condition complicates technology evaluation by increasing the standard deviation of repeated measurements even within one field. However, we need to ask ourselves: isn't this the real condition farmers have to deal with? Might it be that farmers' rejection of technologies developed on-station is due to the fact that they do not stand the real world farm environment? Special experimental designs are available to account for this soil micro-variability, and such methods of spatial adjustment should be used to get the most out of on-farm trials (see for instance, Leiser *et al.*, 2012). In conclusion, researchers should not insist to use traditional experimental designs for reasons of "statistical security" but use their inspiration to develop schemes that allow for real on-farm progress.

How can we further improve on-farm testing? The first condition is to represent spatial biophysical variability at varying scales. An interesting and also economically viable option is to start at the village scale, since if the trials succeed, neighbour farmers will mimic the introduced technology. Who knows the village terrain variability best? It should be the farmers, since they often work the terrain since decades. The experience in the CODE-WA project shows that farmers' terrain knowledge is depending on settlement duration and population density equalling intensity of land use. In this respect a spatial trend could be observed from the north to the south. At the very northern Sahelian site Warzou in Niger, all terrain was used, no fallows or forests were present any more. At the most southern site Piisi in Ghana (northern Guinean ecological zone), farmers were unable to mark the precise village territory boundaries, since there were still land resources available not attributed to any of the villages around. At three from four sites, reasonable indigenous terrain maps could be produced with differing investment. At the site with the youngest settlement in Burkina Faso, this exercise failed. These people were expelled from their traditional habitats when a national park was established.

At the northernmost site Warzou, it was amazing to experience the exactness of the farmer-made village map, of which the boundaries and terrain units were established simply by asking the owner about the properties of his field. In this case the only help provided was a high resolution (QuickBird) satellite image. The outcome was verified by scientific soil mapping. Farmers' distinction of terrain units was more detailed compared to what was possible based on the World Reference Base for Soil Resources (WRB, FAO, 2006). The reason was that farmers integrated several terrain and not only soil criteria. Apart from soil texture, these criteria were soil surface aspect, present and potential vegetation, and crop performance.

Figure 2 shows results from wood ash microdosing experiments, a technology especially developed within the CODE-WA project for subsistence farmers cropping on sandy Sahelian soils (Arenosols according to WRB 2006, FAO, 2006). Pearl millet and cowpea showed in these experiments exactly the yield order predicted by the local farmers, with the preferred Jigawa soil highest yielding and Jampali as problem soil (reason for weak performance still not known). The cowpea experiments also proved the farmer statement that Jampali terrain is only suitable for cowpea production. And for cowpea it is only there that wood ash fertilisation increased production though not statistically significant.

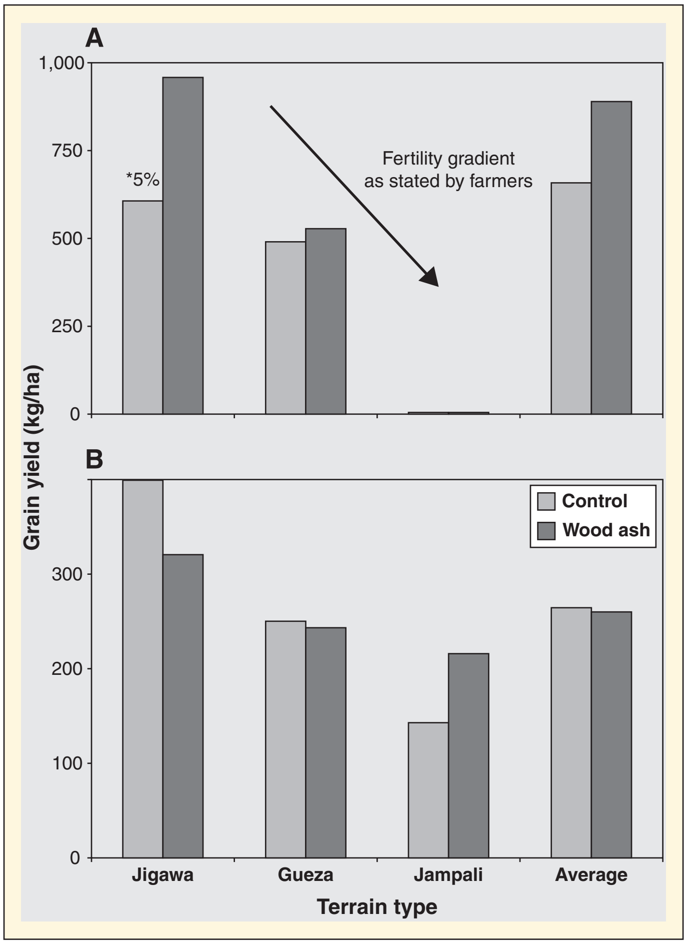

Figure 2. Average grain yield of pearl millet (A) and cowpea (B) with and without wood ash microdosing (2g per pocket) on terrain types differentiated by farmers at the Sahelian site Warzou in Niger.

Statistically significant differences at p=0.05 occur only between treatments for pearl millet yields on Jigawa terrain and between Jigawa and Jampali terrain types. The last group of bars corresponds to the average of the values for the three terrain types.

What can we learn from these results? First of all, it makes sense to consider local terrain knowledge and typology for experimental site choice. Doing so, experimental results can lead to tailored recommendations, which is not to be expected based on random site choice or a choice depending on availability ("where we have always been" strategy). In the case of wood ash microdosing and with the help of the local population, it was possible to develop fairly specific and targeted recommendations: wood ash microdosing is a technology especially well suited for women with extremely poor and sandy soils distant to the settlements. In fact women have access to the (limited) wood ash resource which they produce in their homestead by using dominantly fire wood for cooking. Women under the given conditions in Warzou have reduced access to land, often crop smaller surfaces on the least fertile land at the boundaries of the village territory, and women have less transport capacity. Therefore a no-cost technology which efficiently uses household remnants with low weight in an efficient way (direct application to roots, not broadcasted) is highly appreciated.

In addition, wood ash microdosing increases on Arenosols the minimum

yield and reduces yield variability which fits well into the risk reducing strategy of subsistence farmers (Herrmann, unpublished).
Our conclusion from this experience is that any kind of technology option should face as early as possible the real world farm conditions and then lead to specific recommendations taking the biophysical variability and social context (including gender) into account (see Adesina and Baidu-Forson, 1995). And last but not least, researchers should keep in mind that even in the case a technology is best suited for a given site, single farmers might not apply it since they do not dispose of such a site. Consequently, developing a technology for this farmer should be the next step.
Finally, based on the fact that biophysical variability exists among and even within fields, we should say "good bye" to one-fits-all solutions even at the field scale. This idea is already further developed in the concept of precision farming in industrialised countries, so why should we keep it simpler in the developing world?

• Agro-phytodiversity

At all spatial levels, vegetation responds to variation in biophysical conditions by changes in growth and/or diversity. At the regional level and climate dependent, we see in West Africa a zonal distribution of vegetation starting with tropical rainforest and Guinea savannah at the coast transgressing *via* Sudanian savannah to the Sahelian type of vegetation. At the local scale, vegetation types are further differentiated by relief and soil distribution affecting nutrient and water distribution. Under Sahelian conditions, gallery forest can be found along water courses and thornbush savannah on dry laterite plateaux.
Also farming systems respond in the same manner to biophysical variation. From the coast to the inland with decreasing rainfall, the major staple crops change from maize over sorghum to pearl millet. At the local scale under Sahelian conditions pearl millet dominates the vast cover sand domains and sorghum is planted only on more loamy soils or in small depression with additional lateral water gains. So diversity is ex ante an intrinsic concept of agriculture in order to adapt to variability in biophysical conditions, optimise output and diversify risk.
A logical consequence – especially if focusing on subsistence farmers with low input potential – is to rely on the concept of biodiversity also to face the recent challenges. Just to give an example: if the length of the crop growth period fluctuates between the years, different crop varieties with adapted growth cycles will respond best to seasonal conditions. Therefore, we want to elaborate in the following on the strategy used in the CODE-WA project, and on pre-requisites for success of the "biodiversity" strategy.
First of all, we can distinguish different levels of diversity, which can also be linked to spatial scales: species, varietal, and intra-varietal diversity. Agronomic research in West Africa focused in the past very often on crop and varietal diversity. However, going deeper into analysing farm welfare and cropping systems, also use of wild species and the genetic structure of landrace populations need to be considered. That is why within the CODE-WA project we introduced the term *agro-phytodiversity*, which means all the plants and plant products which contribute to the welfare, diet and food security of a farm household. This definition explicitly includes wild plants, non-crop products and traded goods derived from any plants.
It is especially at the drier sites where wild plant species contribute to the diet and welfare of farm households. This is simply due to the fact that the surface available for cropping is restricted, crop failure is more frequent, and certain wild plants are accessible for free and offer ingredients (and health services) not available from the crops. In addition, wild plants contribute the majority of fire wood used in farm households.
Crop diversity is restricted by climate conditions (zonal scale), *i.e.* maize is not an adapted crop under northern Sahelian conditions (unless irrigation is available) and as a result of aridisation it vanished during the drier decades. In general, the number of potential annual staple crops increases in West Africa towards the south with increasing rainfall and growing season length, thereby allowing for tuber crops for instance. Leguminous crops have their centre of diversity in the sub-humid tropics. In addition soil type diversity (due to increasing relief and lacking cover sands) and water availability for irrigation increases in the same direction. An example for the increasing number of crops on the climate gradient with increasing rainfall is given in *table 1* taking the CODE-WA sites as examples.
In contrast to crop species diversity, we noticed that varietal diversity was higher in the northern Sahel. Especially sorghum, pearl millet, cowpea and groundnut showed a much higher number of varieties in Serkin Hauossa and Tominian than in Nobere and Wa. We suppose that at the northerly sites the "poorer" species diversity is partly compensated for by a higher varietal diversity.
With few exceptions, the introduction of totally new species failed in the short time frame of the CODE-WA project (3-4 years). Farmers are reluctant to adopt

Table 1. Cultivated crops identified in group discussions with famers at the four CODE-WA project sites (order arranged according to frequency within the groups cereals, legumes, tuber crops, and others).

Serkin Hauossa, Niger Northern Sahel	Tominian, Mali Southern Sahel	Nobere, Burkina Faso Southern Sudan	Wa, Ghana Northern Guinea
Pearl millet	Sorghum	Sorghum	Sorghum
Sorghum	Pearl millet	Pearl millet	Maize
Maize[R]	Fonio	Maize	Pearl millet
Cowpea	Maize	Rice	Rice
Groundnut	Cowpea	Cowpea	Cowpea
Bambara nut [R]	Groundnut	Groundnut	Groundnut
Cassava [R]	Bambara nut	Bambara nut	Bambara nut
Hibiscus	Potato	Sweet potato	Soya bean
Sesame	Cassava	Cassava	Cassava
Okra	Sesame	Taro	Yam
	Hibiscus	Egg plant	Sweet potato
	Chili pepper	Sesame	Potato
	Okra	Cotton	Okra
		Tomato	Pumpkin
		Okra	Hibiscus
			Tomatoes
			Chili pepper
			Eggplant

R: very rare.

new species since they cannot determine the risk associated. Other issues that arise are that new species neither have established marketing possibilities nor do farmers know how to process or use them. Exceptions were the introduction of *Cassia tora*, which farmers at the northernmost site knew as wild species, and off-season cropping of various irrigated vegetable species, whose introduction was accompanied by training, repeated provision of seeds and other inputs, and organisational support. This shows that species introduction requires a rather high investment and long-lasting support. It is easier to promote species about which farmers have already minimal background knowledge. And the case of *Cassia tora* shows that still wild species exist which should become subject of domestication and breeding in order to better serve the rural populations.

It is much easier to convince farmers to experiment with varieties of crops in use. In fact, West African farmers are very keen to experiment with new varieties (Ouedraogo *et al.*, 2010).

Within a climate zone, crop pheno- and genotypes vary, best expressed by local landraces (e.g. for pearl millet diversity in Niger see Mariac *et al.*, 2006). At all locations of the CODE-WA project and for all major crops, different landraces/varieties were detected. At the field scale, farmers partly respond with varietal diversity to differences in fertility caused by micro-variability (Bürkert, 1995). Seeds are often distributed along neighbourhood or kinship relations leading – in a spatial sense – to nested use.

A major CODE-WA project concept was to provide new crop varieties with differing growth cycle length in order to enable farmers to adapt to season length variation. The shortcoming of this concept is that farmers have only limited space that allows for varietal conservation. Women – due to smaller surface available – stated to be able to conserve 1-2 varieties, men 3-5. These statements appear questionable especially for open-pollinating crops like pearl millet. Therefore, promotion of social organisation for varietal conservation seems necessary in order to distribute this task and build varietal conservation on more shoulders. This could either happen *via* kinship or neighbourhood groups or by local to regional farmer organisations. The latter option appears advantageous since it is only from a certain size that additional (semi-) professional services like seed stocking, transport, marketing, etc. can be provided.

Table 2. Number of lost or about to be lost and introduced crop varieties identified in group discussions with famers in the Sahelien and Guinean CODE-WA project sites.

	Serkin Haoussa, Niger, North Sahelian site		**Wa, Ghana, North Guinean site**	
Crop	**Lost**	**Introduced**	**Lost**	**Introduced**
Pearl millet	4	7	0	0
Sorghum	3	7	0	0
Maize	-	-	0	1
Rice	-	-	0	0
Cowpea	3	7	0	1
Groundnut	4	0	0	0
Hibiscus	2	3	0	0
Sesame	1	1	0	0
Okra	Unknown variety	0	0	0

NB: No variety of rice was lost or introduced in Wa but the existing variety has increased in use; in Serkin Haoussa, maize, cassava and bambara nut crops are lost or very rare.

CODE-WA surveys showed that the turnover of varieties was higher at the drier northern end of the climate transect, while for the southern end nearly no changes were reported by the interviewed farmers for the last decades (*table 2*). This fact can be explained by the Sahelian droughts reducing the average effective crop growth period, and the lower buffering capacity caused by in general lower local agro-phytodiversity. In short, Sahelian droughts did not only influence staple crop yields but in general biomass production. However, in contrast to expectations, the varietal diversity did not decrease. Formerly used (long duration) genotypes were simply exchanged against others with generally shorter growth cycles compared to the originally dominating landrace.

Local landraces, especially of pearl millet, exhibit a variable degree of intravarietal genetic heterogeneity, for example for flowering time (Haussmann *et al.*, 2007; Haussmann *et al.*, 2012), which allows them to produce at least some grain each year despite high climate variability at place. This intra-varietal genetic heterogeneity seems to be a result of long-term in-situ diversifying selection and contributes to adaptation and yield stability over time *via* population buffering (Haussmann *et al.*, 2012). In fact it could be shown that intra-varietal variability of 10 pearl millet landraces from Niger for flowering time was positively related to the rainfall variability at the collection site, pointing to the inherent population buffering mechanism due to genetic heterogeneity in those landraces (Moumouni, 2011, unpublished data).

However, according to the criteria of the International Union for the Protection of New Varieties of Plants[3], "improved varieties" are supposed to be distinct, uniform and stable (DUS criteria). Based on the above mentioned landrace description and the observation of extreme inter-annual climate variability, one CODE-WA working hypothesis was that an optimal genetic variability of a variety exists for adaptation traits that allows to reduce the production risk for farmers and assures a stable minimum yield. Achieving the latter, rather than a maximal yield, is in fact the strategy of subsistence-oriented farmers. Therefore, the legal definition of "improved varieties" should be revisited at least for WASAT conditions. Future research should produce further evidence that non-uniform "varieties" have a lower production risk and higher medium-term average yield than genetically uniform varieties. If so, this could explain the difficulties of introduced uniform varieties to "beat" the local landraces/varieties as experienced also during the CODE-WA project. A consequence

[3] UPOV, http://www.upov.int

could be to lay more emphasis on local, farmer-supported breeding initiatives.
In conclusion, as research community we need to recognise the extreme biophysical variability in the WASAT. The strategy of nature is to respond to this fact with biodiversity. There are good reasons for the research community to act accordingly rather than to search for streamlined uniform answers. However, there are a number of constraints to the biodiversity approach, which are biophysical, cultural, social and economic in nature. Consequently, mono-disciplinary approaches did not lead to success in the past. We should learn from this failure and adapt. One option is to work in interdisciplinary teams and to include from the beginning the farmers' view.

Optimised farmer participation as key factor to speed up research impact

In a R4D environment, the advantage of the researcher is his/her formal education, the developed skill of logical thinking and the independence from the local socio-cultural context, allowing for free thoughts. The advantage of the farmer is the better empirical knowledge of the environment, its variability and resulting constraints for cropping. Also she or he is better off with respect to judging limits related to socio-cultural and socio-economic conditions. And farmers define the risk they want to take with respect to all farming operations.
Already these short reflections make it obvious that in an R4D context, best progress is probably achieved if the advantages of the different stakeholders are combined in a joint effort. This means optimising the role of the different stakeholders. While researchers have more potential to guide the innovation process and access to external resources, farmers can give ex-ante information on urgent needs (relevance of innovations), constraints for potential solutions as well as adaptation needs. Therefore the CODE-WA project tried to optimise – and not maximise – farmer participation. The inclusion of local terrain knowledge for optimising innovation testing was already mentioned above. Here two other procedures will be presented which deal with researcher-mediated inter-farmer innovation communication and an optimised procedure for innovation adoption and adaptation.

The Vertical Farmer Exchange Visit (VFEV) as a tool to exploit and develop farmer innovations

The term climate variability from its conception includes extreme events, like droughts but also excess water by heavy rainstorms. Due to the strategic decision to position CODE-WA sites along a latitudinal climate gradient in the WASAT, experiences to deal with arid as well as humid environments exist within the participating local communities. Having the idea of climate change induced higher frequency of extreme events (= increased climate variability) in mind, the idea lies near to promote exchange of the existing accumulated local skills among farmers. Consequently, the VFEV methodology was developed which is intentionally based on knowledge exchange across (in West Africa NS or on a map vertically succeeding) climate zones.
The basic idea was that farmers from generally dry environments train farmers from more humid ones how to deal with dry spells, and that the farmers from the high rainfall environments teach the others how to manage excess water. However, the practice showed that knowledge exchange covered much broader themes.
The major constraints in organising the knowledge transfer were language barriers. These could be overcome by building national teams consisting of farmers on the one hand and national scientists, extension workers, technicians on the other, the latter providing translation. A striking example for the efficiency of this approach was the presentation of tomato production in different environments. While in northern Ghana tomatoes are planted on ridges to avoid water stagnation in the root zone within the rainy season, in southern Burkina Faso tomatoes were produced in furrows between ridges using gravity irrigation during the dry season. This example highlights that a standard production technique at one site can represent an innovation in another environment. Therefore we can deduce that many practical solutions already exist in farmer hands and only need to be communicated and transferred to other environments. And why should farmers not communicate to farmers who are aware of the practical importance of single measures and who speak the same practice-oriented language. In fact, visual communication aids such as hand drawn sketches and videos of processes and were the most appreciated by farmers.
During the exchange visits soon the communication exceeded pure production related practices and resulted in joint preparation of dishes and ceremonial exchange of seed materials. Especially the preparation of dishes gave additional motivation for the exploitation of specific crops (e.g. *Moringa oleifera*) which were known at certain sites but so far had no practical use. Finally farmers stated that the pure visit of sites with a totally different environment functioned as mind opener and resulted in new ideas. One such idea was to use fonio (*Digitaria exilis*), which is a cereal cash crop used to prepare even convenience food products at the Malian CODE-WA site, as a fodder crop under drier

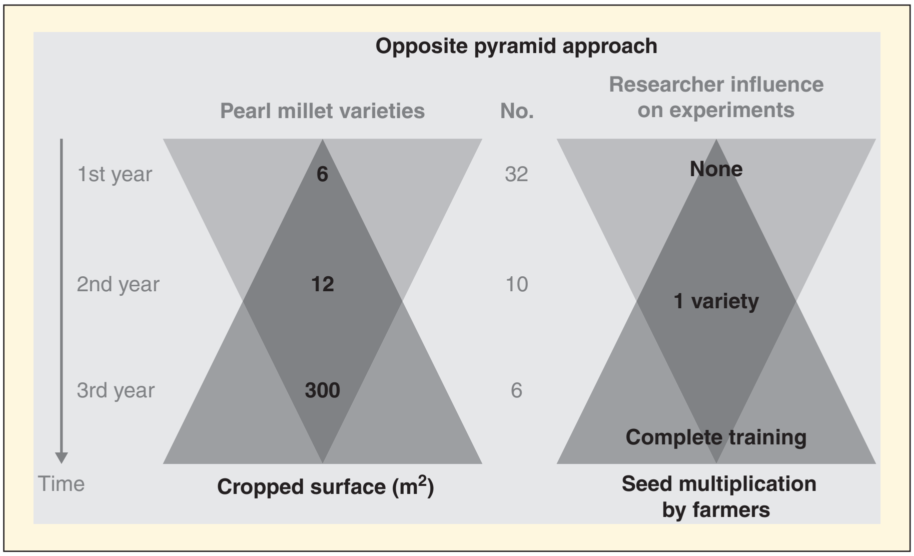

Figure 3. The Opposite Pyramid Approach taking pearl millet variety testing as an example.

conditions in Niger, where pastures have vanished.
The lesson learned from the VFEV activities is that with little effort and money but by simple exchange of ideas between farmers, new local innovations can be supported and then jointly evaluated by research and practice.

The Opposite Pyramid Approach (OPA): a strategy for efficient testing and sustainable adoption of innovations

R4D aims at the development of solutions. In the best case the solutions should be adopted by farmers. Therefore a combined research, evaluation and training approach was developed within the CODE-WA project. Here we take pearl millet varieties as example (*figure 3*). Applying the Opposite Pyramid Approach, testing of introduced varieties began with a great number of diverse varieties against the local checks. From year to year the number of tested varieties was reduced based on evaluation by local farmers until a number was reached in the third year which could potentially be conserved by local efforts. In the same timeline the cropped surface (number and surface area of trials) was continuously increased in order to approach real farming conditions and favour adoption. While in the beginning, the experimental conditions were determined by the researcher, with time more autonomy was given to the farmer to decide about management practices. In the last year farmers had absolute autonomy to apply their own sowing density, fertiliser regime and to use mixed cropping schemes. Simultaneously farmers were trained in varietal conservation and professional seed production. It appeared that none of the farmers had any idea about the crop differences with respect to reproductive biology, so emphasis was on the difference between self- and open-pollinating crops.
The participating farmers described this approach as one that a father would apply to his son. First the son follows the advice of the father and then he gets liberty to develop own ideas and to adapt to personal conditions.
Applying this approach, scientific data could be gained especially in the first year when partly the same varieties were compared under standardised conditions across the four CODE-Wa sites. The following years brought insights how introduced varieties compare to local landraces/varieties under farmers' field conditions and which traits are locally decisive for variety adoption. This way both parties achieved their goals and local adaptation as well as adoption was encouraged. At the end of the project at all sites more than one variety was chosen for community-based seed multiplication or further testing. At two sites, professional seed multiplication was envisaged as additional income opportunity and to support large scale seed dissemination.
In conclusion, the different participatory research activities have shown the advantage to include local knowledge, expertise and action. Using local terrain classification led to a better understanding of experimental results. Communicating local management expertise led to innovative thinking and developments at corresponding sites. Joint testing with variety selection based on local reasoning and combined with training in seed production led to reasonable adoption rates. Consequently, optimising farmer participation and capacity strengthening in R4D endeavours leads to faster progress for all parties.

Conclusion

Climate change and climate variability put increasing pressure on WASAT agro-ecosystems and related local societies. In this biophysically limited environment, new approaches are necessary to speed up agricultural development and adaptation and adoption of new technologies in the widest sense. Increasing agro-phyto-diversity coincides with the risk-spreading strategy of subsistence-oriented farmers. However, at species level increased diversity is hard to achieve. It needs a whole framework of supporting action like establishment of value chains, training on crop cultivation and use, including recipes for food crops.
At variety level it is difficult to increase diversity at present due to the low capacity of farmers and low organisational level of WASAT communities to produce seeds of a diverse set of cultivars, especially for allogamous crops. Farmer organisations could provide the framework for variety conservation and provision in the future. The development of the professional seed sector should not simply try to mimic developments in industrialised countries but carefully check for the best options. There is reason to believe that intra-varietal diversity offers advantages in the WASAT environment. Legislation and research do need to take this into account.
Optimised participation of farmers in R4D projects showed to be efficient in speeding up innovation adoption. Creativity is needed to find the right level of farmer participation and provide motivation. In the long run, farmer organisations should take responsibility as partners of research as long as national extension services are weak. Farmer organisation personnel should be trained to conduct experiments along their own interests especially with respect to varietal adaptation and locally adapted management options. This is best executed with the help of national research institutions which can assure the minimum quality requirements for such testing and additional supportive input.
Finally, especially international researchers need to acknowledge that sound progress in WASAT agriculture can only be achieved if better mutual understanding between researchers and farmers is achieved.

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