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Article

Extension Agrometeorology as the Answer to Stakeholder Realities: Response Farming and the Consequences of Climate Change

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Abstract: Extension agrometeorology is applied in agrometeorological extension work to advice and serve farmers. In agrometeorology, response farming has been developed decades ago. Climate change complicates response farming, but does not alter it. This paper reports on new operationalization of that response farming in new educational commitments in agroclimatology. It is explained how "Science Field Shops" are an example in Indonesia. This was based on a thorough analysis of what climate change means for farmers in Asia. For Africa, we report on eying the training of agrometeorological extension trainers ("product intermediaries") in West Africa, based on a thorough analysis of what climate change means for farmers in Africa. We also compare experience with reaching farmers in

South Africa and farmer communities in Zambia, as new forms of supporting response farming, all under conditions of a changing climate. The paper, for the first time, connects results from four different programs the senior author is taking part in. There is first and foremost the need for training material to make it possible for the product intermediaries to participate in training extension intermediaries. This should, particularly, bring new knowledge to farmers. With what is presently available and with new approaches, climate extension should be developed and tested with farmers in ways that improve farmer preparedness and decision making.

Keywords: changing climate; response farming; extension agrometeorology; Indonesia; Ghana; South Africa; Zambia

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1. Introduction

Climate change has highly complicated the livelihood of farmers in the developing world and will continue to do so as the most recent work of the Climate Change And Food Security (CCAFS) program shows qualitatively and, where possible, quantitatively [1,2]. In some cases there are indications where and why it will go wrong [3,4]. However, as long as the coupling of General Circulation Models (GCMs) based climate models and crop impact models can, for quite some time to come, absolutely not be done with the necessary accuracy for decision making on adaption to climate change [4,5], neither climate modeling nor climate prediction can be of much operational assistance to farmers in most of the world [6]. In detail:

> "*In assessing impacts (on crops) and any required adaptation options to abate them, future projections of climate and agricultural systems play an important role. Nonetheless, future outlooks of agricultural production and food security are contingent on the skill of GCMs in reproducing seasonal rainfall and temperatures. Thus, accurate climate change projections are important for developing appropriate and effective adaptation strategies (……). In improving projections, enhancing our understanding of important modes of variability, (……), the responses of plants to (new) environmental factors are key steps to reducing the uncertainties that can potentially constrain adaptation*" [4].

Recently [7] pictured extension agrometeorology as a contribution to sustainable development and defined it as agrometeorology that attends to (i) local suffering from weather and climate and persistent ways to diminish it, and (ii) windows of opportunity that (micro)climate offers "on farm". They argued that this has to be done in a participatory approach. This should lead to the establishment of agrometeorological services by and with farmers. It means first and foremost field work with farmers (see also [8]). We define agro-meteorological/-climate services as "All agrometeorological and agroclimatological knowledge and information (including suitable indigenous technologies) that can be directly applied to try to improve and/or protect the livelihood of farmers" (e.g., [8,9]). It was concluded that extension agrometeorology should join hands with other extension fields to mobilize production and protection forces in a multi-functional agricultural production (see also [10]) where trees outside forests (see also [9,11,12]) would play an important role [7].

Now we have the advantage that, in agrometeorology, response farming has been developed decades ago. The principle was widened in [13] and also further developed into a Farm Adaptive Decision Optimization, in [14], widening its fields of operation but keeping the village farmers as focus [15]. In an evaluation, [15] reviewed that response farming is a method of identifying and quantifying, statistically or otherwise, seasonal rainfall variability and (un)predictability and related risks, addressing these risks at the farm level. Originally, response farming was limited to rainfall events, but coping with weather and climate (and often soil) disasters, as well as using windows of weather and climate (and often soil) opportunities, are other forms of responding to weather and climate (and often soil) realities. Services such as advices on design rules on above and below ground microclimate management or manipulation, leading to appreciable microclimatic improvement: shading, wind protection, mulching, other surface modification, drying, storage, frost protection, *etc*., also belong to such "response farming" agrometeorological services ([15], see also [8]).

Climate change complicates, but does not alter this [13]. Below we report on new operationalizations of that response farming in new educational commitments in agrometeorology. Some were carried out with farmers in Indonesia since 2008 in the new form of "Science Field Shops" [16–19]. This was done in Gunungkidul (Yogyakarta) and Indramayu (West Java). It was based on a thorough analysis of what climate change means for farmers in Asia [16,20,21]. For Africa, we report on eying the training of agrometeorological extension trainers ("product intermediaries") in West Africa in a new way. This is based on a thorough analysis of what climate change means for farmers in Africa [22–24] and on very recent experience with reaching farmers in South Africa [25,26] and farmer communities in Zambia [27]. These are new forms of supporting response farming. It is important to indicate here that in the above mentioned literature [16,22] we consider that as to climate change, three issues have serious consequences for farmers: (i) global warming; (ii) (increasing) climate variability; and (iii) occurrence of more (and possibly more severe) extreme meteorological/climatological events. Response farming has to do with these three issues [16,22]. Due to the fundamentally different ways weather and climate are approached for knowing their future, we consistently talk in this paper about weather "forecasting" but climate "prediction" (see also [25]).

2. Information, Advisories, Services

Let us first define weather/climate "information", "advisories", and "services". In our view, information in meteorology/climatology is passive in the sense that there is no indication coming with that information on how to use it. "Raw" weather forecasts and climate predictions are examples. Information with recommendations on how to use it, or information otherwise made more client-friendly for solving specific problems, may be called advisories. However, dialogs between senders and receivers are still not necessarily involved. In the USA, an advisory is only an official announcement or warning, while, for example, in India it is a recommendation that is, however, neither compulsory nor enforceable. Establishing such advisories with farmers in their fields should be called services. In that case we have dialogs between farmers and extension. In that case farmers are assisted to carry out the advisories (establish the services) in their fields, jointly, with extension intermediaries and/or farmer facilitators (selected by the farmers from among themselves) who were shown and trained how to do so.

In our fields of work, with small scale and resource-poor farmers, agrometeorological and agroclimatological services (climate services for agriculture) should be established in farmers' fields, with well-trained extension intermediaries and/or (with the upscaling to communities in mind) sufficiently knowledgeable farmer facilitators [16]. These services are then agrometeorological advisories, accepted in their most client-friendly form by these farmers, and molded by them into what could be actually applied in their fields. The services will that way also be jointly validated by farmers and extension. The same applies to other fields of applied agricultural sciences.

From the above, it follows that data and information are useful building stones only if used to build advisories and, preferably, services that can be established in farmers' fields. We report below only on the roads to such results.

3. Developments in Indonesia

3.1. Introduction

From their respective experiences in collaborative ethnography in Asia and participatory agroclimatology in Africa, Winarto and Stigter in 2008 jointly established field work in agrometeorological learning in Indonesia [28]. In this set-up it was proposed to a small group of participating farmers to (i) measure rainfall in their own plots on a daily basis (Figure 1); (ii) make agro-ecosystem observations in those plots, including on soil conditions, water management, pests and progress in crop growth, where necessary also on a daily basis; (iii) discuss these matters with each other and participating scientists and students; and (iv) translate their learning experience in understanding the consequences of climate change for their farming initiatives [29].

Figure 1. Unusual weather patterns helped farmers see the relationship between daily rainfall quantities (as measured by the farmer pictured), soil moisture and the growth of their crops in Indramayu, Indonesia. Photo by Yunita Winarto [29].

These were farmers that carried out rainfed monocropping and multiple cropping. It should be realized that only rainfall is so variable in time and space that it has to be measured in all plots by all participating farmers. This applies anywhere in Africa, Asia and Latin America. All other macroclimate parameters can be taken from the national grid, where necessary; all microclimate parameters can only be well measured by automatic weather stations *in situ*. This is done here and there in industrialized countries in relation to pests and related diseases but nowhere in developing countries [28].

These farmers in Gunungkidul had taken part in a Climate Field School of limited duration but were this way familiar with some aspects of management and manipulation of water in their fields [22,23]. We introduced, from the beginning, sessions in which several scientists of Gadjah Mada University, Yogyakarta, where we were based for this work, were available to answer questions and discuss problems farmers had. In the course of time, these meetings of farmers with applied scientists were called "Science Field Shops" [16]. Such real dialogues with farmers became the way to assess and carry out a response farming to climate change, based on the agrometeorological learning process initiated [15].

In 2009 we were relocated to the Universitas Indonesia in Depok (near Jakarta), on whose behalf we started a set-up of Science Field Shops in Indramayu (north coast of West Java), using our Yogyakarta experience. Presently we work there with about 50 farmers that make the above mentioned measurements/observations and discuss them monthly with each other and with students led by at least one scientist. There are three kinds of (mainly) rice farming carried out here: irrigated, half irrigated (because water only reaches them part of the growing seasons) and rainfed, also pumping groundwater to save a crop where necessary. From the beginning, farmers and applied scientists have jointly tried to relate measurements and observations to rice yields and to yield comparisons between growing seasons, between the same growing seasons in different years and between farmers/fields.

In that way we catch consequences of climate change (as monitored) and consequences of management (sowing, transplanting, water, fighting pests, using fertilizers *etc*.) the way they can be understood with farmers' agrometeorological learning [22]. Also here farmers can ask any agricultural production related question that we then try to answer and also discuss with them in dialogues during Science Field Shops [15]. This way we get answers that apply to stakeholder realities. Farmers now do not feel abandoned, as they largely are by the government extension services, including the pest and disease observers from the Ministry of Agriculture.

3.2. Climate Predictions

The way in which we presently bring the NOAA monthly "ensemble" climate prediction information to the participating farmers in Indramayu, is a more client friendly information that may be called an agrometeorological advisory (see Section 2). We try to derive the most likely start of the main rainy season and also indicate whether the dry season may be expected to be normal. However, our advisory, given as a scenario for the seasons concerned, remains a qualitative one, based on the raw climate prediction information that we receive from NOAA. For example three recent advisories to our farmers (early January, early February and early March, 2013) were:

> *The seasonal scenario for West Java: "a normal reasonably rainy wet season and a normal start of the dry season that may be expected to be itself normal as well". and*

> *The seasonal scenario should therefore read: "till April the season is expected to remain normal but could go into the wetter end of the normal range". and*
>
> *The seasonal scenario prediction for the farmers then becomes: "The rainy season will continue as normal but might have rains in March/April at the lower end of what is near normal and it may have an early cessation. The dry season may be expected to be dry indeed with possibly a somewhat earlier start".*

The reality from the Indramayu farmers daily measurements was (for a rainy season that had only started by mid-November) a month of February that had appreciably less rainfall than January and March. So from that point of view, the scenario given in January was helpful but that given in February was suggesting the wrong trend within the rainy season, like that in March. But of course these trends remained within the "normal range" of the rainy season as a whole, after a late start. After two years we will ask the farmers through questionnaires about their experiences with these simple seasonal climate scenarios (see [30] on our approach). Dialogues will then help to improve this arrangement.

Of course these messages are translated into Bahasa Indonesia before they are sent via SMS to the farmers concerned. Now when do such advisories become a climate service for agriculture? When such an advisory is discussed with these farmers, and when they can ask questions related to understanding of and acting upon these seasonal scenario advisories, the agrometeorological advisory on climate prediction has got the form of an agrometeorological service. Dialogues will then help to improve this arrangement (Section 2).

3.3. Other Agrometeorological Services (Climate Services for Agriculture)

Part II of [9] has examples of other agrometeorological services and how they were established on-farm (see also [8]). Such services can never be established as a routine without well-trained extension intermediaries and/or farmer facilitators (selected by the farmers from among themselves). What the scientists of the examples in [8,9] actually do is linking science-based (agro)climatological products and problem solving in the agricultural production environment for various categories of farmers and extension intermediaries. This particularly contributes to increasing the useful operational applicability of weather science, climate science and various fields of agricultural sciences for extension agrometeorology. This must be seen as a contribution to science itself [26].

4. Three Theorems of Agrometeorological Extension to Build New Response Farming

We have not long ago reviewed our work on extension agrometeorology [7] as well as on agrometeorological extension [16]. We illustrated how the recent experience in Indonesia very well fits the accepted extension theories and practices [16]. For this paper we review this extension experience in the following essential theorems, not worded this way before. A theorem is a general proposition that is not self-evident but proven by a chain of reasoning. Some of the experience from Africa was shown in [8,9]. The African examples highlighted below in Section 5 may be considered to confirm the sense of this approach.

> *Extension training should start at the institutions that deliver the agrometeorological and agroclimatological products on which advisories and services should be based.*

Reasoning: the weather forecasts, climate predictions, early warnings for agriculture (including those for pest outbreaks), water management issues, microclimate management and manipulations issues, and all other science based information products come from scientific institutes and weather/environmental services. Therefore, that is where extension training should start. In the Climate Field Schools organized in Indonesia, they forgot to thoroughly train these trainers first (e.g., [29,31]). Only recently in some places they start to propose to actually do this [22,32–34],

> *The product intermediaries should in the end train extension intermediaries who work closest with farmers, for the latter intermediaries to be able to deliver advisories and where necessary/possible establish services with farmers in their fields. Science Field Shops can be used to start up such training.*

Reasoning: the present situation is that intermediaries, where they still exist and are sufficiently operational, have hardly been trained in the consequences of climate change for farming and farmers. If they participate two to three years in new educational commitments like Science Field Shops, they should be able to largely take the positions of the scientists that can withdraw and only cooperate when there are (new) problems for which they can assist to find (new) solutions [16].

> *The extension intermediaries that work closest with farmers should deliver advisories and services to farmers and where applicable establish these services with farmers in their fields. Also these intermediaries can first be trained by participation in the Science Field Shops until product intermediaries exist with enough experience and training.*

Reasoning: those extension intermediaries that are supposed to work closest with farmers must in the end be trained by product intermediaries. In the time that it will take to train the latter, also the former can be trained by participation in new educational commitments like Science Field Shops [16].

The conclusions from these extension theorems are our starting points here. However, extension intermediaries are almost everywhere much too small in numbers to serve all farmers of an area/country. It is here that the farmer facilitators come in as another agent that initially needs to be trained in Science Field Shops. Only farmer to farmer extension will in the end be able to reach all farmers that want new knowledge and experience under the conditions of a changing climate. In summary, there is a great responsibility with the scientists involved that have to organize themselves in new educational commitments with farmers to set up field work like Science Field Shops. This is a new participatory way to understand farmers' vulnerabilities, problems and questions, handling response farming under the conditions of a changing climate [15,20].

5. Developments in Africa

5.1. When It Started and Beyond

From the late eighties and (more successfully) in the nineties as well as much more recently, some agrometeorologists in Africa participated in on-farm research and worked with farmers in solving problems, but nowhere was, for various reasons, official extension part of that picture [9]. This also applies to China with agrometeorologists at provincial weather services [9]. With climate change becoming more and more important, these issues became more and more urgent [9,22–24].

On paper, we want to bring researchers, practitioners and users in the field of African climate together to share knowledge and accelerate the harnessing of climate science to the service of decision makers and communities in Africa [35]. But enhancing climate sciences output for Africa is only one of the necessities. If we are not able to considerably increase absorption of climate sciences operational results for decision making within African communities, we are again only filling shelves in libraries or storing material in space within "tablets", but we do not get results used in villages anywhere. Also in the Global Framework for Climate Services, hardly any established system for climate services provision for agriculture is available anywhere near African communities; nor are there many user interface platforms and is there much capacity building in place to make absorption of warnings and other science based products possible. This also applies to other fields than agriculture [26]. This has to do with logistics, but also with the low skill that most products still have [9].

We will report here on a few recent attempts to change that situation with various new response farming approaches.

5.2. Ghana

The work in Ghana was contemplated and frame worked some years ago but became more serious in the course of 2012. It aims at what our first theorem of extension is about, that training of extension trainers should start at the institutions that are supposed to generate science-based agrometeorological products. Countries with agricultural production systems as given farming systems, established as suitable for the conditions before climate change set in, must now, under conditions of a changing climate, use knowledge based systems in order to:

(a) Adequately address the new decision making and other old and new needs of the farming communities;

(b) Develop agro-meteorological/-climate products/services with and for farmers;

(c) Successfully develop and implement new suitable support services for agricultural production (extension, policies, institutions, infrastructure, research, education and training) for their decision making.

Agro-meteorological/-climatological services must be further explored. They include among others:

(A) Specific weather forecasts for agriculture, applied and evaluated with farmers [36,37], seasonal climate predictions (see Section 3 above), early warning messages and other disaster preparedness attempts, applied and evaluated with farmers [9];

(B) Design of new cropping/farming systems that can face the new requirements of a farmer first paradigm under a changing climate (e.g., [1,2]);

(C) Generating and supporting a rural response to climate change in agrometeorology [28], which will boil down to improving farmer preparedness and decision making;

(D) Testing and re-evaluation of indigenous coping strategies for the conditions of a changing climate (e.g., [26]).

In view of that, there is a need for reference material and sources of information on extension agrometeorology as there isn't any teaching material that links applied science to development of decision making on relief measures for the farming community in the West African sub-region (and the rest of Sub-Saharan Africa, for that matter). The necessity of coping with climate change makes such educational material even more indispensable. The objectives are to develop training material on extension agrometeorology that can be used as reference material, source of information and training guide for product intermediaries. We have started to write that material. Table A1 (in Appendix) gives a draft Table of Contents. The present content of 282 PowerPoint slides has been recently prepared in Ghana (Stigter and Ofori, unpublished) and has been discussed at length with a local team of scientists. Much work has still to be done.

5.3. Zambia

In [27] the set up of a Community Agrometeorological Participatory Extension Service (CAPES) in Mujika Region, Zambia, was reported. In short, since the community agrometeorological participatory engagement is not meant as an academic exercise of only creating a Community Information Dissemination Plan (CIDP), but must address the community problems, the engagement has to be implemented to get the overall benefits. This works through community involvement under the leadership of the CAPES team. At this stage each stakeholder performs specific tasks as expected, following the CIDP. This stage addresses the overall community problems related to improved food security and livelihoods. This is the most active part of CAPES, where farmers implement the strategies. This process continues in the community's life as long as it is necessary as community livelihood cannot change overnight. Implementation is important for addressing and testing the suitability of strategies in addressing climate related community problems [27].

Farmers participate in the dissemination of climatic knowledge using the multi-disciplinary climatic knowledge dissemination modes such as vernacular radio, radio listening clubs, farmer to farmer dissemination, public small and large group meetings, field experiments, field days, *etc*. Farmer participation makes the CAPES special because after receiving climatic training they engage in knowledge dissemination using different dissemination modes, compelling one another to effective participation and utilization of climate knowledge. The ultimate result is that of an improved livelihood [27].

The current smallholder farmers make decisions (such as choice of crop, variety, planting time, planting density) and select crop management options (such as on thinning the crop, division in time for the use of fertilizers, applications of pesticides) that will fit the season. These choices can then be tested using so called "mother-baby field trials", to find their suitability for the ongoing season. Selected or volunteer farmers manage the baby trials at various locations on their farms while the mother field trial is replicated and is managed by the researchers. Opportunities such as field days held at the mother field for sharing the gained knowledge from these trials are accorded at appropriate times. Lessons learnt at such field days improve on farmers' future decisions, given the advisories/services developed [27].

Farmers require training in the use of climate knowledge where after the presentation of the current climate prediction farmers make decisions based on that prediction, which they test during the season. The increased interaction on climatic knowledge between researchers and community is promoted by field and home visits where farmers will receive additional extension service regarding understanding of climate knowledge and timely on-farm corrections. This will enhance future farmer decision making for improved crop productivity [27].

Farmer to farmer dissemination of knowledge is the most widely used form of climatic knowledge dissemination by farmers within the community. It takes place almost everywhere, any time, given the opportunity. As climatic knowledge is shared by their fellow farmers, who are credible, other farmers easily accept and adopt climate knowledge [27].

5.4. South Africa

Since 2008, research was done on the use of operational weather and climate information in farmer decision making by resource poor as well as commercial farmers in the south-western part of the Free State province, also known as the Modder/Riet catchment, South Africa [25]. It was found that most resource poor farmers in the South-Western Free State, originally, were not familiar with agrometeorological products but relied on their experience and traditional knowledge for farming decision-making (see [26]). Most commercial farmers, having more resources, performed better, compared to the resource poor farmers. Many used (some) agrometeorological advisories before and others were easily introduced to (more of) them. We will therefore continue here mainly with the resource poor farmers that need extension most.

The approach of this research was the establishment of study groups in six towns in the area. The analytical results from questionnaires conducted in 2008 and 2012, with partly overlapping farmers, indicated that farmers in the South-Western Free State differ in agricultural practices, interests, needs, experience, and skills. Therefore, we need provisions of tailor-made products for crop production, animal husbandry, agroforestry, and veld management, respectively. The research, especially, exemplified case studies linking science-based products/advisories and problem solving in the agricultural production environment, for various farmers, where applicable, through extension intermediaries. In the case of this study, they were disseminated to the study groups, of which the composition had been proposed by extension intermediaries involved. This study demonstrated that participating (commercial and) resource poor farmers used weather forecasts and climate predictions for agriculture and other science based agrometeorological advisories during most of the study period [25].

The study groups presented a very diverse situation in terms of experiences, challenges, and needs that are related to their farming. For example, agricultural production in some parts of the study area can be optimal under supplementary irrigation where soil requirements are suitable. The consequences of increasing climate variability needed greater emphasis as to farmer's ability to develop on-farm coping strategies and interventions. A successful farmer should understand the local trends in climate change and how agricultural outcomes are influenced. For example, the concept of response farming prepares the farmer to be aware of past and future climatic conditions and of the extent of increasing climate variability and related dangers and interventions to reduce vulnerabilities. Analyzed long-term rainfall data assisted the farmers to select suitable crops for the area for diversification and sequential planting and determining the suitable planting dates and planting densities. Crop models were used to generate and evaluate a series of management practice scenarios. These outputs from the analyzed climate data and crop models were used to develop advisories that were tailor-made for the farmers. The study for example identified potential production areas for vegetables, herbs/spices, food grains, oil seeds, fruits, and other products such as cotton and other fibers. Application of crop models such as Ehler's model and Eco-Crop 2 revealed the thermal and water requirements of these crops which are either fully or partially met in various parts of the catchment [25].

Participation of farmers in a series of monthly innovative workshops created a conducive environment for knowledge exchange and training. It is advisable to conduct on-farm visits prior to the workshop/meeting days for proper preparations. This was to ensure that the monthly workshops were well-planned, productive, and informative events. The manner in which this study was structured enhanced a bottom-up approach since it allowed participative approaches in close contact with the study groups, improving farming development by closing the gaps existing between developers, suppliers and users of agrometeorological knowledge and understanding. The best outcome of this study was that farmers learnt new things and shared their information and experience. This farmer to farmer extension should be recommended for reaching the highest number of farmers in an area. The remaining challenge for agrometeorological advisories/services providers is to supply reliable and skilled forecasts/predictions and other science based information for agriculture through dissemination methods that suit the farmer [25].

6. Discussion, Comparing the Various Results

Implementation of the engagement of farmers with the CAPES team in Zambia, including house and field visits, may be compared to Science Field Shop meetings, both being attempts to jointly address farming problems. In Zambia, the mother-baby field trials give additional experimentation for discussions and comparisons, where in Indonesia all participating rice farmers meet once a month to compare the results of their measurements and observations in their own plots. Both extension attempts consider the undertakings to be long term strategies. In Zambia, there is already more dissemination by using radio and, after the experimental phase, farmers will continue on their own, assisted by local extension; the same applies in Indonesia after the Science Field Shops phase. Both agrometeorological extension strategies indicate that in the end farmer to farmer dissemination of knowledge is the most important upscaling strategy.

As in Zambia there is community involvement from the beginning, upscaling starts earlier and makes use of the community structures. In Indonesia the learning started one scale below this and the farmer to farmer extension is needed to involve the communities in which the farmers live. The participating farmers in Indramayu are scattered over a rather large area, those in Zambia are from one large community of several villages near to each other. The latter should be considered an advantage at the first upscaling.

The study groups established in South Africa, and in the course of time the monthly workshops with these farmers, prepared by visits prior to these meetings, may also be compared with the Science Field Shops. It is clear that in South Africa, Zambia, and Indonesia, an intensive long-term contact between farmers and scientists involved was the first prerequisite of any success. Extension is nowhere sufficiently trained and active to play a role worth mentioning, and where they participated, they were part of the trainees more than of the trainers. However, Zambia's CAPES could be of subsequent importance in South Africa because "study groups" could in due course be replaced by "communities" as core of the extension methodology.

Once introduced to science-based approaches and products, farmers are most eager to understand the differences between local and scientific knowledge and either combine them, or change, mainly into the use of science-based products. The participating farmers were most varied in South Africa and least so in Indonesia, due to the cropping and farming systems involved. What everywhere is still missing is, first qualitatively and then quantitatively, the influence that the use of science-based products has on yields. Indonesia worked on this most closely by attempting comparisons of rice yields between farmers, between annual seasons and between seasons in the same calendar year.

In South Africa, the work was least field based although improvements in the crop situations were important and readily observed. The mother-baby field trials of Zambia are clearly an important way to observe improvements of knowledge inputs. However, it should be realized that the low yields in Africa need protection from the consequences of climate change most, but can relatively easily be improved. The rice yields in Indonesia vary from total regional failure, due to pests, floods, and drought, to between 5 and more than 10 t/ha on average in normal years everywhere.

Farmer to farmer extension is overall emphasized as crucial, while the high degrees of participation and bottom up extension show to be absolute necessities for any successful involvement of scientists. The more frequently and directly scientists (in the early phases) and well trained extension intermediaries (in the not too far away future) are involved in supporting field management under conditions of a changing climate, the more likely improved livelihoods for farmers become.

7. Conclusions and Recommendations

Extension agrometeorology related activities of new response farming, like found in Indonesia, Ghana, South Africa, and Zambia, should be continued and scaled up. Initial operational answers to the changing agricultural reality of stakeholders were found in South Africa and Zambia, and are developing in Indonesia. There is, first and foremost, the need for training material (Appendix, Ghana case study, but also in development in the other cases) to make it possible for the product intermediaries to participate in training extension intermediaries delivering agro-meteorological/-climatological advisories/services to farmers under conditions of a changing climate. This should, particularly, bring new knowledge to farmers [16,21,25,27,38–40]. However, they should also be warned for the low skills that many of the products still have, and will continue to have for quite some time to come (e.g., [9,23,30,31,40]).

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Conflicts of Interest

The authors declare no conflict of interest.

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Appendix

Table A1. Set up of syllabus to train agrometeorological extension trainers (product intermediaries).

Extension Agrometeorology for an Agrarian Response to Climate Change A Training Guide for Trainers of Agrometeorological Extension Intermediaries in West Africa for Conditions of a Changing Climate
General Introduction
PART I. What Can Be Learned From Experience in Other Parts of the World
Prologue
Section I.I. Agrometeorology and Extension Agrometeorology: Further Definitions, Consequences and Use

Table A1. *Cont.*

Extension Agrometeorology for an Agrarian Response to Climate Change A Training Guide for Trainers of Agrometeorological Extension Intermediaries in West Africa for Conditions of a Changing Climate
Section I.II. Pitfalls in Extension Agro-Meteorology: Examples from Drought, Wind Erosion and Desertification—Warnings and Combats
Section I.III. Reaching Farmers: Agrometeorological Services in a "Farmers First Paradigm" and Attitudes towards Clients
Section I.IV. Institutionalization of Educational Extension Commitments: "Science Field Shops" and "Climate Field Schools" for the Establishment of Agroclimatic Services, Using Locally Developed Agrometeorological Products
PART II. Considerations of Climate and Society: What Climate Change Means for Farmers in Africa
Section II.I. An Introduction from Recent Literature
Section II.II. Climate Change, What Does it Mean for Farmers in West Africa?
II.II.A. Global Warming
II.II.B. Increasing Climate Variability
II.II.C. More (and Possibly More Severe) Climate Extremes
II.II.D. Contributions from Agriculture in Diminishing Greenhouse Gases
PART III. Testing and Evaluation of Cropping/Farming Systems (New or Traditional) and How They Fit into the Presently Increasing Climate Variability and Climate Change
- using material from CCAFS: "Recalibrating Food Production in the Developing World: Global Warming Will Change More Than Just the Climate" and
CCAFS: "Impacts of Climate Change on the Agricultural and Aquatic Systems and Natural Resources within the CGIAR's Mandate"
PART IV. Identification/Documentation of Further Problem Solving for Decision Making Needed at the Farm Level under African Conditions
-- Vulnerability Assessments
-- Other Adaptations and Mitigations Needed in African Agriculture
-- Agro-ecological Approaches in Formulating and Implementing African Strategies
-- Multiple Cropping in Africa
-- Crop Rotation in Africa
-- Developing a Communication and Problem Identification Strategy at the Farm Level, an Asian Example
PART V. Rainfed Farming General Considerations of Extension Issues
1. Rainfall characteristics and data analysis
2. Biophysical response to weather and climate
3. Guides to crop and crop varieties selection
4. Guides to crop growth characteristics and yield monitoring
5. Microclimate and designs for water conservation
6. Pests and disease incidence/control as affected by weather and climate
7. Influence of weather and climate on crop selection
8. Short range weather forecasting for agriculture: suitability, absorption and use in decision making
9. Crop yield models applied in production management
10. Scenarios for the growing seasons from simple climate predictions for agriculture
PART VI. Irrigation Agriculture General Considerations of Extension Issues
1. Crop water requirements and their calculations for water management decision making
2. Soil/plant/water relationships
3. Pests & diseases incidence/control as affected by weather and climate

Table A1. *Cont.*

Extension Agrometeorology for an Agrarian Response to Climate Change A Training Guide for Trainers of Agrometeorological Extension Intermediaries in West Africa for Conditions of a Changing Climate
4. Influence of weather and climate on crop selection
5. Short range weather forecasting for agriculture: suitability, absorption and use in decision making
6. Crop yield models applied in production management
7. Scenarios for the growing seasons from simple climate predictions for agriculture
8. Guides to crop and crop varieties selection
9. Microclimate and designs for conservation/protection
PART VII. Extension for Soil and Crop Protection
1. Crop protection from wind (structures and their agrometeorological designs)
2. Other crop protection (from heat/sun, frost/cold, floods, high intensity rains and hail as other meteorological hazards)
3. Soil protection (structures/agrometeorological designs)
4. Crop protection as pest and diseases control and agrometeorological implications
PART VIII. Related Matters
VIII.I. Extension Experience
VIII.II. The Role of Scientists
VIII.III.A. Participatory Rural/Land Appraisal
VIII.III.B. Participatory Farm Management Methods
PART IX. Training Matters Country by Country
IX.I. Local Curricula
IX.II. ICT Use: Ghana
PART X. Input Use Patterns: Ghana
PART XI. Innovative Insurance Products for the Adaptation to Climate Change Project: Ghana