WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR AGRICULTURAL METEOROLOGY

CAgM Report No. 104

AGROMETEOROLOGICAL SERVICES: REACHING ALL FARMERS WITH OPERATIONAL INFORMATION PRODUCTS IN NEW EDUCATIONAL COMMITMENTS

Prepared by
C.J. Stigter

Geneva, Switzerland

November 2011

Chairperson, Publications Board
World Meteorological Organization (WMO)
7 *bis,* avenue de la Paix
P.O. Box No. 2300
CH-1211 Geneva 2, Switzerland

Tel.: +41 (0)22 730 84 03
Fax: +41 (0)22 730 80 40
E-mail: Publications@wmo.int

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INTRODUCTION

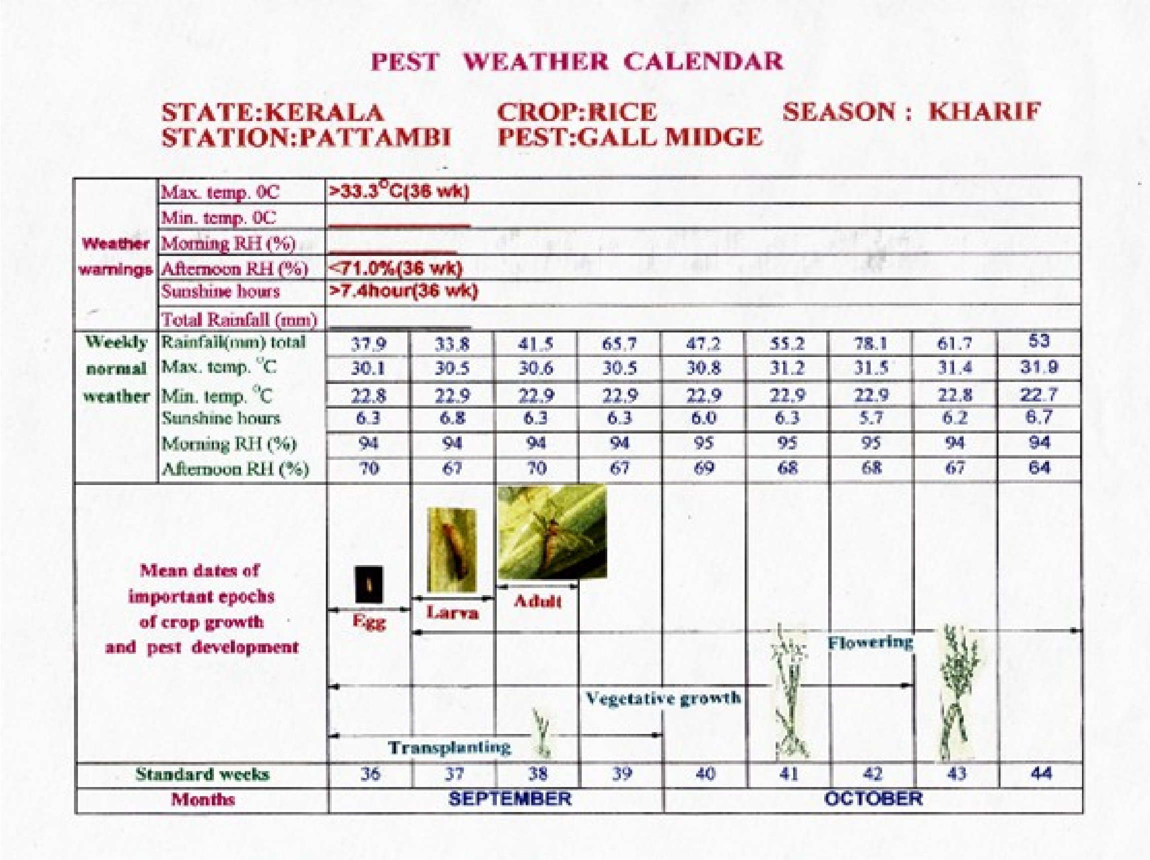
In Mali, West Africa, before and during the full growing season, a team of applied scientists in the National Meteorological and Hydrological Services (NMHS) receives through a telecommunication network, rainfall data, soil moisture data, agronomic preparedness proposals and other necessary information from selected farmers' fields. In one of the earliest examples of response farming, using knowledge on weather, climate, soils and yields of recent decades and available weather and climate forecasts, the team gives advice on the cultural practices of the growing season. This ranges from type of crops/varieties to be selected and sowing dates till harvest planning. Such advices can lead to yield increases of 30 percent on average. These are agrometeorological services.

In some alley cropping, the shade of the trees is an important tool against weeds and surface drying before their pruning, such as in the "Inga alley cropping design". This must therefore be seen as an agrometeorological service to the farmers concerned. A system was designed in which the conditions found in virgin tropical forests were mimicked: minimize weed growth – first by tree shading then by leaf mulches – and recycle nutrients, including phosphorus, by using thick-leaved nitrogen fixing trees providing sufficient biomass under the local sub-humid to humid climate conditions, without too much limiting competition. After this system worked well with maize crops in Costa Rica, Honduran slash and burn farmers further developed the alley cropping of Ice Cream Bean (*Inga edulis)* with maize and beans and with pepper as well as vanilla. Moreover, the trees do provide a reasonable amount of fuelwood.

In India, there is a growing list of weather based pest and disease models. Their use is exemplified by a pest weather calendar for "Gall midge" in rice (Figure 1). Conditions for weather warnings are given together with weekly normal weather conditions for September and October and the mean dates of important periods of crop growth and pest development. This way, moments for operational action can be determined. This is an agrometeorological service. It is planned to carry out experiments at all 127 Agricultural Meteorology Forecasting Units (AMFUs) for further developing weather models for important pests and diseases for major crops and to derive agrometeorological services from these models.

In Cuba, the "SAT" agrometeorological service of drought forecasting and early warning became operational in the Camaguey provincial weather service in November 1994, just in time to predict in September 1995 the 1995-96 winter-drought disaster, which brought the government to declaring "drought emergency". This drought became known as the "Camaguey cattle emergency" and established the relevance of "SAT", of which improved versions are now available. The users are governmental authorities with end users in the agricultural and insurance sectors. Governmental institutions rely very heavily on the existence of this agrometeorological service. It has been fundamental in all adaptation measures and actions taken to relieve the negative impacts of drought in Camaguey, including saving nearly 100,000 heads of cattle and the maintenance of milk production levels.

In Sudan, East Africa, the Gezira University received a request to study the mechanism by which a Eucalyptus shelterbelt traditionally used in Egypt was most efficiently keeping disastrous wind blown sand out of parts of the Gezira irrigation scheme, where it buried crops and prevented irrigation canals to carry water. This led to the design of improved shelterbelts that were subsequently applied in the region. Such a design of microclimate improvements for wind protection and settlement of wind-blown sand is an agrometeorological service (Figures 2A, B, and C). Another agrometeorological service developed in Central Sudan is the design of further protection of the sand source area with the most suitably managed biomass of selected trees and grasses studied for their sand settling properties.



PEST WEATHER CALENDAR

STATE:KERALA CROP:RICE SEASON : KHARIF

STATION:PATTAMBI PEST:GALL MIDGE

		36	37	38	39	40	41	42	43	44
Weather warnings	Max. temp. 0C	>33.3°C(36 wk)								
	Min. temp. 0C									
	Morning RH (%)									
	Afternoon RH (%)	<71.0%(36 wk)								
	Sunshine hours	>7.4hour(36 wk)								
	Total Rainfall (mm)									
Weekly normal weather	Rainfall(mm) total	37.9	33.8	41.5	65.7	47.2	55.2	78.1	61.7	53
	Max. temp. °C	30.1	30.5	30.6	30.5	30.8	31.2	31.5	31.4	31.9
	Min. temp. °C	22.8	22.9	22.9	22.9	22.9	22.9	22.9	22.8	22.7
	Sunshine hours	6.3	6.8	6.3	6.3	6.0	6.3	5.7	6.2	6.7
	Morning RH (%)	94	94	94	94	95	95	95	94	94
	Afternoon RH (%)	70	67	70	67	69	68	68	67	64
Mean dates of important epochs of crop growth and pest development		Egg	Larva	Adult				Flowering		
		Transplanting			Vegetative growth					
Standard weeks		36	37	38	39	40	41	42	43	44
Months		SEPTEMBER				OCTOBER				

Figure 1. Example of pest (Gall midge) forecasting information for rice in India. [Courtesy NCMRWF (India)/L.S. Rathore]

Figure 2A. Sihaimab shelterbelt studied for winds, wind blown sand and sand settlement near the south-western edge of the Gezira irrigation scheme (Central Sudan). [Photo Kees Stigter]

Figure 2B. Close up of the shelterbelt of Figure 2A, with equipment for measuring saltating sand and integrated wind speed with a shaded Piche evaporimeter. [Photo Kees Stigter]

Figure 2C. Sand settlement within the shelterbelt of Figure 2A. The edge formed by gravity is about ten meter inwards from the wind facing edge at the right hand side. [Photo Kees Stigter]

An example of an agrometeorological service related to the management of natural resources developed by farmers comes from Ningxia Autonomous Region in Western China. The region is about 200 km south of Yinchuan, and only receives 100–200 mm of rainfall annually which makes it susceptible to drought and wind erosion. Over large areas, farmers cover the surface with artificial fertilizers, and then with about 10 cm of pebbles (collected with trucks from dry river beds). This is a pure application of agrometeorology in serving the livelihood of farmers which accomplishes the following outcomes: (i) prevents soil and fertilizers to be blown away by wind; (ii) warms the soil under abundant sunshine to a required temperature, including frost prevention; (iii) makes the rain infiltrate into the soil with minimal evaporation losses from the surface; (iv) forms a suitable seedbed for watermelons that are sown through the pebbles into the soil using the available water and fertilizers (Figure 3). These watermelons are sold with great profits in major cities in China! This example from China also shows that traditional farmer innovations can be adapted to agrometeorological services for a New Countryside, the most recent government policy approach of rural areas of China.

The above examples will be extended below within categories of such services which also include irrigation scheduling, zoning/mapping and reduction of contributions of agricultural production to global warming. They are examples of designs of agrometeorological services carried out for and with farmers to improve and protect the growing conditions of carefully selected crops and animals, sometimes assisted by trees with their power to use nutrients and water from deeper layers and to give protection from strong winds, heavy rains and high radiation (Figure 4). Such designs of multi-story growing systems may use combinations of scientific and indigenous knowledge that also use the understanding of productive, protective and resource sharing properties of naturally existing growing systems (Figure 5). Under the conditions of a changing climate, the need for agrometeorological services that assist farmers to address increasing climate variability and more frequent and numerous extreme events has only become more urgent.

Figure 3. Water melon plants growing in a suitable microclimate on soil moisture below a mulch of pebbles in Ningxia Autonomous Region, western China. [Photo Liu Jing]

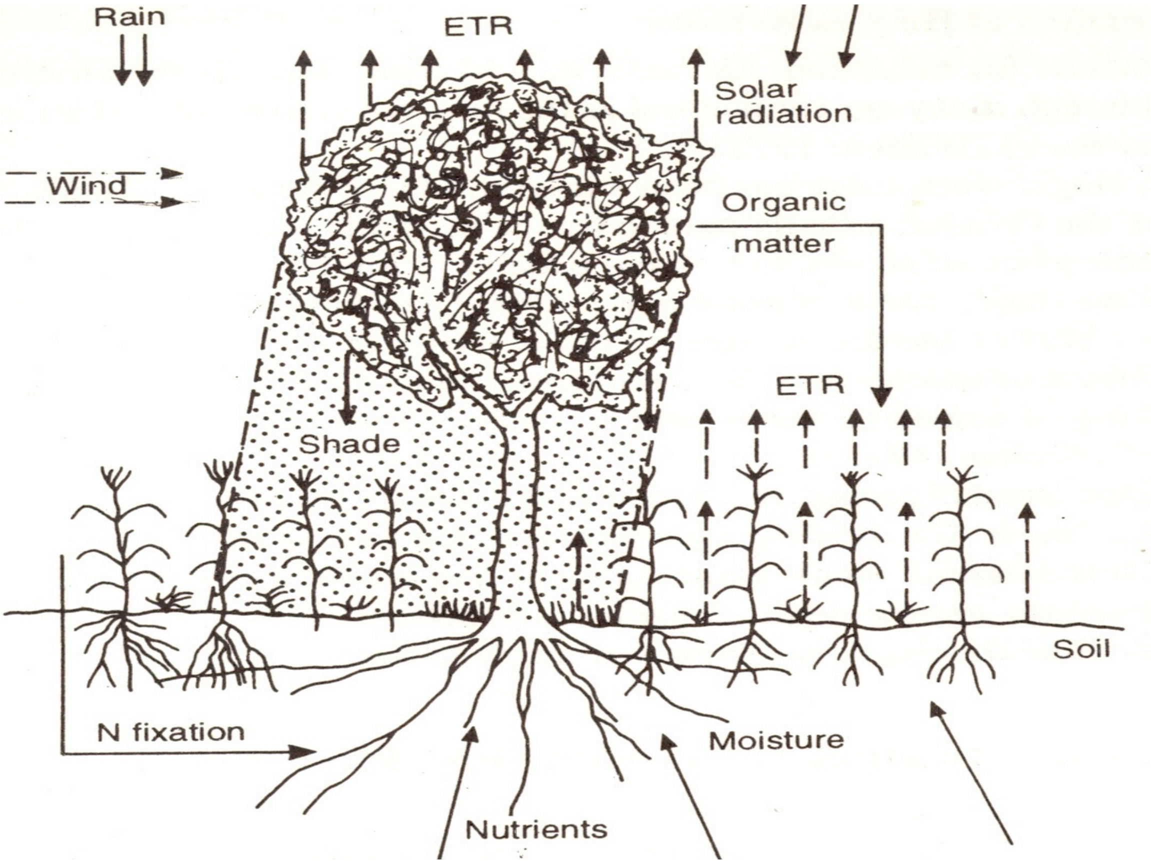


Figure 4. Interaction of a tree with its environment. [Courtesy INRA, Paris (France)]

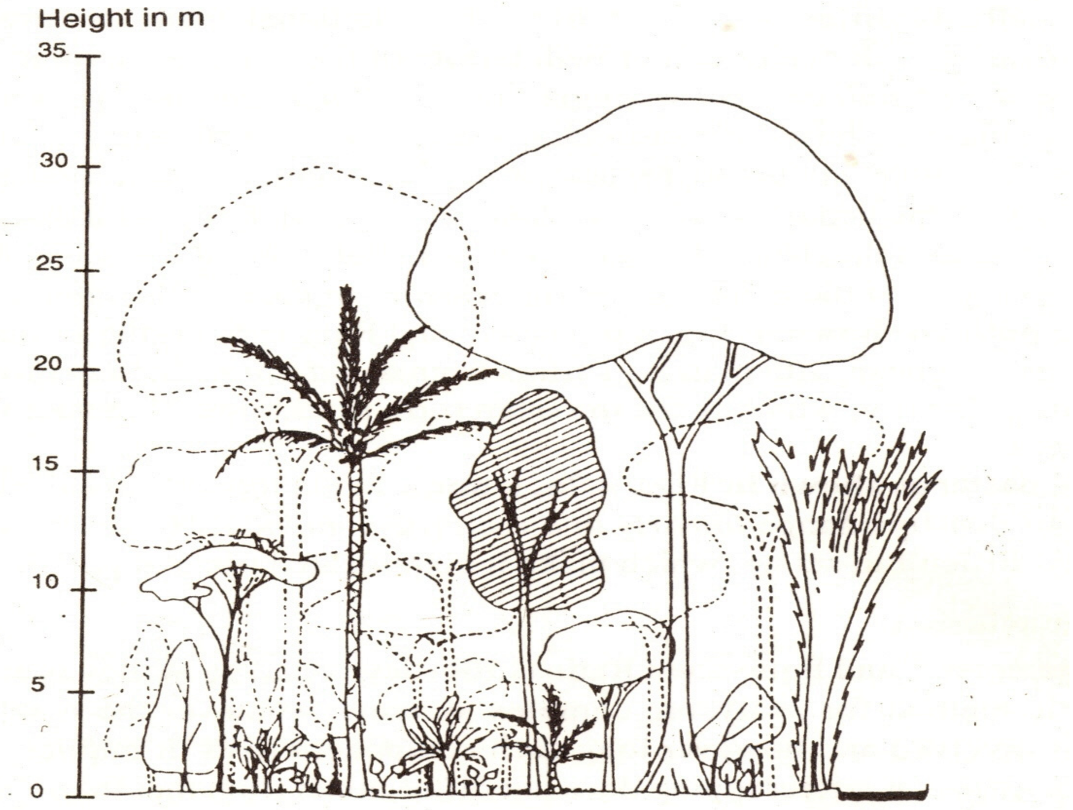


Figure 5. Spatial occupation of a village forest garden in Java (Indonesia) with four main storys. (Courtesy INRA, Paris (France)/G. Michon).

BASIC CONCEPTS AND SITUATIONS

As illustrated above, agrometeorology by definition investigates adaptation strategies to weather and climate in raising crops, trees, livestock and fish. It studies water, heat, air and related biomass development in the agricultural production environment, including disasters, and their socio-economic consequences for farmers as decision makers. This leads to agrometeorological services for response farming with irrigation scheduling, early warnings, microclimate manipulation and the application of weather and climate forecasts in a changing and increasingly variable climate.

We must first distinguish between (i) Agrometeorological (Advisory) Services (A(A)Ss), which handle the organizational aspects of (a) collecting and generating agrometeorological information, advisories and services with the participation of applied scientists and well differentiated farmers and (b) providing information, giving advisories and establishing services to/with farmers, and (ii) these agrometeorological services themselves as operational information products for various target groups of farmers, depending on their farming systems, their occupations and their levels of income and formal education.

The A(A)Ss will be part of the National Meteorological and Hydrological Services (NMHSs) but agrometeorological services as products may also be generated by Extension Sections of agricultural research institutes and universities (which in the course of time may be called “Services Departments”). Co-ordination must be organized in strong collaboration with A(A)Ss. Later, possible organizational and institutional details will be discussed but A(A)Ss should be organized as close to the farmers as possible, the way that it is done in India as described below with respect to disasters. One important reason for this is that many agrometeorological services will have to do with coping with disasters.

BOX 1: RESPONSE FARMING

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. The hypothesis is that solutions to farming problems may be found by improved forecasting of expected rainfall behaviour in the cropping season(s). Response farming means adapting cropping to the ongoing rainy season by guidance of agronomic operations, using past experiences, preferably from interpretations of meteorological rainfall records, with support from traditional expert knowledge where available (Figure 6). We are talking here about onset of rains, total amounts, duration (variability, including dry spells and their lengths), rainfall intensities, frequency of rain days, average daily rates of precipitation, distribution of rainfall over the seasons, ceasing of rains, etc., that are of interest to farmers. Climate change just brings complications to organized response farming. Given the indications for increasing climate variability and change of the climate in terms of rainfall, this will have to be adapted to those new conditions by also using any available climate forecasting, limiting the period in the past over which the experience can be used and adapting the information to local soils and topography. Response farming has so far been limited to planning for rainfall events, but the preparative coping with weather and climate (and related 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.

In India, effective and accountable local authorities are considered the single most important institution for reducing the toll of natural and human induced disasters. The country’s day to day administration revolves around the District Collector who is also in charge of all the relief measures at that level. There are sub-divisions and tehsils (administrative entities of local government). The lowest unit of administration is the village. All these tiers of administration function as a team to provide succour to the people in the event of disaster. It would be very helpful indeed if the establishment of agrometeorological services could be guided at the lowest administrative level. However, examples from China show how far agrometeorological information still was from farmers' conditions and actual services only somewhat more than ten years ago. Projects to improve that situation are ongoing. Establishment issues will therefore be dealt with later in this report.

BOX 2: HISTORY OF AGROMETEOROGICAL SERVICES

In the oldest literature dealing with agricultural meteorology from science to application, services were under "methods in agricultural meteorology". In the late sixties, there was, as the WMO Commission for Agricultural Meteorology (CAgM) brochure on its first fifty years expresses it, "satisfaction with the transfer of new knowledge and information to end users at the global, regional and national levels", but such end users were policy makers, not farmers. Agricultural practice in a wide sense came into the picture in the seventies and became a focus in the eighties with a wider and more practical approach. In the nineties we started to look at the dynamic realities of agricultural production and organized an increasing participation of developing countries, using contributions to operational agrometeorology and economic benefits as important issues. The third WMO Long Term Plan (1992 – 2001) placed earlier objectives within the context of a newly formulated challenge: "to be of service to sustainable agricultural production in the framework of sustainable development", as the same CAgM brochure tells us. In 1994, Prof. Kees Stigter emphasized, as then president of the CAgM, that "users of agrometeorological information should be the focal point of all our work", while in Havana in 1995, CAgM talked about "strengthening members' indigenous capabilities to provide relevant meteorological services to agriculture and other related sectors". It was the CAgM Workshop in Ghana in 1999 that started to distinguish agrometeorological services and their four support systems: data; research; education/training/extension; and policies. In the present decade, we have understood that the mentioned support systems may drive the action support systems needed and that most often the most urgent ones are on mitigating impacts of disasters. But the resulting applied agrometeorology seldom reaches the livelihoods of farmers in developing countries, with a majority of farmers with low degrees of formal education and low communication and organizational infrastructures (Figure 7). Solutions of farming problems are not worked on or the solutions/livelihood connections are poor. Could this be different? This report illustrates how and under what conditions.

Whatever experience there is in developing countries points towards the importance of organizing A(A)Ss after all at the lowest administrative levels (and from there upwards), making use of extension intermediaries to do the work (see further below). It is often suggested that examples could be studied from developed countries to learn from, but the literature shows little public A(A)Ss in these countries, apart from many important aspects of large scale water management (flood protection, drought mitigation through water availability). The first essential difference is the level of formal education of most farmers. Currently, farmers in developed countries mostly help themselves or are assisted by unions and information/legislation provided by the governments. Over time, many left the profession because of economic problems and some diversified through new roles in fruit growing, bee keeping, raising of exotic animals, mushrooms, fish, etc. or in recreational set ups. In agrometeorological advisories in Europe and the USA there is a strong trend towards commercialization, something that in developing countries will only be possible for the richest and best educated group of farmers.

Figure 6. Discussion on traditional knowledge with local experts in Mali. [Courtesy Mali National Meteorological Services/D.Z. Diarra]

Figure 7. Cup anemometers and shaded Piche evaporimeters as ancillary anemometers in farmer demonstration projects in Matanya, Central Kenya. [Photo Kees Stigter]

SERVICES AND COMPLEXITY

An analysis of the current state of affairs in agriculture shows that the adverse effects of nature can be handled and that efforts to develop and apply technology for intensification in a variety of farming systems are under way, but that sustained adoption of technology by the mass of smallholder farmers has not sufficiently taken place. The need for capacity building on an institutional/governance scale runs parallel with the need for capacity building on an extension scale. Agrometeorological services can only really blossom in rural areas where also a "services culture" exists in other fields. Such other fields are, for example, improving education, health care, disaster preparedness and relief activities, infrastructures, credit facilities, agricultural input availabilities, markets, communication technologies. Policies and capacity building in these fields do matter very much.

This means that for the establishment of agrometeorological services one has to take the actual status of the other above mentioned facilities and realistically projected progress/limitations into account. Such knowledge has to be collected as far as agrometeorology is concerned. We must understand how our policies and capacity building in agrometeorology are related to these other fields and to the livelihood of farmers. Only then can agrometeorological products/practices/services be sufficiently feasible, attractive and justifiable and contribute to poverty alleviation.

BOX 3: LIVELIHOOD OF FARMERS

A good definition of livelihood by Prof. Robert Chambers is: "the means to gain adequate stocks and flows of food and cash to meet basic needs, together with reserves and assets to offset risks, ease shocks, and meet contingencies." Almost twenty years ago he argued that in practice the livelihood strategies of poor people, including resource-poor farmers, are often complex and diverse and can be different in the same village. This was very recently confirmed by unique extensive Chinese research. It was also argued long ago by Chambers that we poorly understand the micro-environments of Low External Input Sustainable Agriculture (LEISA). This explains why scientists, if at all interested in applications of their findings, come up with wrong solutions presented along the wrong communication channels. And for the exceptional potentially suitable answers in insufficiently client-friendly ways. The consequences of poverty and vulnerability are not clearly understood nor are the possibilities within farmers' existence. Because operational agrometeorology has to be carried out within the livelihood of farmers, we must be on speaking terms with extension agents, anthropologists, and other agricultural and social scientists as well as development economists. Quoting an article in the Jakarta Post, in Meulaboh, Sumatra, at a meeting of local governments, national and international agencies and NGOs, there were five main reasons that became apparent for the problems encountered in assisting poor people in building or rebuilding a sustainable livelihood after the 2004 Indian Ocean tsunami. A first basic problem in Aceh/Sumatra appeared to be one of appropriate need assessments. By doing this, one would realize that livelihood strategies emerge in response to opportunities, not from preconceived master plans or blueprints. The second important issue was that the biggest challenge facing all organizations working in the affected regions in Sumatra was collaboration and coordination, between agencies and between actors at different levels. Related to the above issues was the observed urgent necessity in Sumatra of attention to a "missing middle layer" in this co-ordination. The three remaining issues in Aceh/Sumatra were all related to policy matters, in which were distinguished (a) environmental issues, (b) infrastructural and market issues and (c) issues related to the lack of base line data and the support to collect and collate these.

As to the livelihood of farmers, it has been shown that four different income-levels of farmers in China treated the technological and related information differently, and their levels of satisfaction were also different. In addition, they appeared to receive the information largely through different channels. When the villagers had similar occupations (planter, cultivator, businessman, village technician, village leader), their information requirements were close to each other, but different income-type farmers again used different media channels to receive the information. This situation has, mutatis mutandis, been confirmed in other developing countries and countries in transition as well.

Because of the above, the actual situation is complex. Many agrometeorological services, including warning systems, have not made the transition from scientific validation to real world application. Why are so many products unused? Logistical barriers to the application of services have to come down or should be eased. These include the following: inconvenience and complexity; added costs; added labour; difficulties to respond timely; unsuitable weather and climate data; unsuitable weather and climate forecasts; interpolation needs; non-existing or not yet most suitable communication channels. For the opening example of this report from Mali, Table 1 shows the factors involved as requirements for such pilot projects. However, when successful, the results are not just simple, as Table 2 shows for that opening example.

In Cuba, difficulties in the drought early warning communication were encountered due to the low development of communication networks linking providers of the service directly with producers at the farm level. In north-east Brazil, enormous difficulties were reported in long term attempts to introduce drought early warning services to poor people. One lesson drawn by Lemos and colleagues reporting on this case is “that the forecast is limited by the socio-economic conditions of the beneficiary population.” This case shows that as a consequence of insufficient knowledge of the conditions that actually shape the livelihood of farmers, applied scientists as well as extension intermediaries have too often insufficiently taken into account local adaptive strategies, not made the right choices in the use of contemporary science, and indeed not understood the overwhelming effect of inappropriate policy environments. At higher decision-making levels such difficulties were appreciably less. Providers in Cuba believe that much more important information for essential decision making can be delivered at all levels of society.

As another example, in the Philippines this was expressed by the local NMHS in 2005 on the INSAM website as follows: “The productivity of a region in a particular farming operation may be increased by the reduction of many kinds of losses resulting from unfavourable climate and weather, and also by the more rational use of labour and equipment (Figure 8). Greater economy of efforts is largely achieved on farm by the reduction of activities that have little value or are potentially harmful. This is what the Philippine Atmospheric Geophysical and

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Table 1. Requirements for Mali Pilot Projects on Response Farming (Collected from scattered literature by Kees Stigter).

- Crop (field) observations
- Soil (moisture) observations
- Routine meteorological observations
- Special meteorological observations (farm rainfall)
- Data management and data storage (bank)
- Provincial NMHS and an equivalent in Agronomy
- Agrometeorological Service (+ multidisc. team)
- Agrometeorological advisories and services
- Agrometeorological Bulletin/News
- Participation of National/Local radio/television
- Agrometeorological extension intermediaries

Table 2. Results obtained in the Pilot Projects on Response Farming in Mali and elsewhere. (Collected from scattered literature by Kees Stigter).

- Better understanding of response farming
- No necessity of re-seeding cereals
- More efficient determination of final plant densities
- More timely weeding
- More efficient spraying (cotton)
- More efficient use of fertilizers (where applicable)
- More efficient water use
- Inclusion of weather (rainy season) forecasts
- Higher yields (15 till 60% have been measured)
- Improved drought impact control
- Better locust (impact) control
- Better planning of agricultural development programs
- Use of local languages

Astronomical Services Administration (PAGASA) Agromet Services are trying to provide, so as to assist farmers in their day to day operations. There is still much to be done and to develop, not only in the accuracy of forecasts and advisories but also in the effectiveness of such services. This also pertains to making sure that climate information and advisories reach the farmers and are understood by them. For in the final analysis, the farmers are the ultimate beneficiaries of these services".

Figure 8. Ridges under construction to conserve water in a slightly sloping field planned for rain-fed rice in Gunungkidul, Yogyakarta Special Province, Java, Indonesia. [Photo Esti Anantasari]

As to the agrometeorological services themselves, one should consider that all agrometeorological and agroclimatological information that can be directly operationally applied belong to such services; to try to improve and/or protect the livelihood of farmers in agricultural production, so yield quantity and quality and income, while safeguarding the agricultural resource base from degradation.

BASIC ORGANIZATION

The core idea was developed and applied in Africa, Asia and Latin America that agrometeorological services can be established with farmers from farmer experience and/or (information) products that are offered by meteorological services, research institutes and universities. Five basic issues have to be addressed in pilot projects for the establishment of agrometeorological services:

1. Determination of needs and problem prioritization and selection.
2. Target group differentiation and fine tuning of information needs assessment and problem definition.
3. Product selection, improvement and targeting (user/client friendliness).
4. Development and establishment of agrometeorological services (risk communications leading to preparedness and mitigations) from those products by applied scientists, government and NGO extension intermediaries and farmers.
5. Upscaling from pilot projects through training exercises.

For the first two basic issues, experience in Africa and Asia indicates that questionnaires (through interviews) with farmers are essential. Otherwise it remains unclear whether the choices were made by farmers or extension or scientists, and in the latter cases whether the choice was at least farmer supported as a priority problem related to their priority needs. For the third basic issue, it should be realized that forecasts, predictions, models, decision analyses, communication methods (including participative research) are tools that only become (information) products when they can be operationally used by others down the line towards farmers for better preparedness and mitigation decisions. As to the fourth basic issue distinguished above, the question is where and how to focus on problems which can be operationally tackled by products (still with the differentiations applied):

- collect existing agrometeorological services of the kind related to explicitly available products identified, if any (Figure 9); determine the communication channels;

- determine which (information) products need to be focused on which priority problems; and which applied scientists (from which institutions), extension intermediaries and farmers should be involved in making these products into services along which communication channels;
- organize the establishment of such agrometeorological services in risk communication (such as in response farming) along the right channels, using extension intermediaries where appropriate.

As to the fifth basic issue distinguished above:

- any agrometeorological service so detected or established with a target group of farmers through certain communication channels (from products operationally used to solve priority problems) in pilot projects, should be considered for upscaling. For example, this may be done through the development of training modules for extension intermediaries (working at the institutions concerned or along the communication channels established) to be used in Farmer Field Schools (FFSs, Figure 10, for details see further below);

- in first instance these will be farmers in the same category of differentiation, because for other groups the best approaches could be different.

In conclusion, the lessons learned still point towards a need to, by all means, bridge the gaps towards the livelihoods of farmers. For any lasting success of agrometeorological services, such bridging should be funded, organized and permanently evaluated through the training of intermediaries. Climate change will make this only more necessary.

BOX 4: CLIMATE FIELD SCHOOLS ALUMNI

In Gunungkidul, Central Java, Indonesia, farmers discussed their experience with changes that they collected as alumni of a Climate Field School (CFS). These CFSs are regular meetings throughout a growing season where farmers come together to learn about various aspects of ongoing weather and climate issues in that season with well trained extension intermediaries. The farmers also provide feedback to these intermediaries as well as share experiences between themselves. They first dealt with changes on plants and animals. One observation indicated that the sound of a certain grass hopper was still a good indication for planting. The reported fact that falling leaves do no longer coincide with starting rains was suggested to be due to false starts. The suggestion was discussed that clearing a forest near the village had caused the change of rainfall regime observed. It was argued that this was unlikely and that the change was due to larger scale phenomena, not local phenomena on a small scale. However, the regional atmosphere definitely had become drier due to clearing the forest and this would also contribute to changes in rainfall elsewhere. The farmers' presentation on crop choice and the following day in the field showed the great knowledge that farmers have acquired on suitable crops and the adaptations they are performing to changing conditions related to climate/weather or market developments. It is therefore a wrong practice to make scenarios for the future based on extension of present practices and systems. Farmers do adapt more often and faster than most often assumed. They need help to do this more efficiently and to disseminate results beyond the local trials, but crop choice is a dynamic practice on most soils and will have to be more so under a changing climate. An interesting issue with respect to changes in weather/climate/season, was the observation of false starts of the rainy season that did not occur in the past. It was explained that false starts are very frequent in drier areas in Africa, where farmers are forced to resow sometimes even more than once. The Mali pilot projects are an example where seasonal information has improved on this practice and this would definitely also work in Indonesia. Climate Field Schools could be very instrumental here. Documentation is one of the missing assets compared to better organized societies and is particularly important under conditions of rapid change as are occurring now (Figure 11). The example of some traditional societies was given where information on changes in plant, tree and crop phenology had actually been preserved.

Figure 9. Multiple shelterbelts in a completely desertified environment, designed as an agrometeorological service to settle drifting sand and get grasses and bushes re-established (successful) and protect potential farm land in the whole area between them (unsuccessful) at Yambawa, northern Nigeria. Communication channels with farmers did initially not exist. [Photo Kees Stigter]

Figure 10. Climate Field Class in Mali. [Courtesy Mali National Meteorological Services and D.Z. Diarra].

Figure 11. Field observations on phenology, pests & diseases, and their documentation, in a Farmer Field School in Gunungkidul, Yogyakarta Special Province, Java, Indonesia. [Photo Esti Anantasari]

CATEGORIES OF AGROMETEOROLOGICAL SERVICES, FURTHER EXAMPLES, APPLICATION CONDITIONS

It has now been generally accepted to distinguish the following ten categories of agrometeorological services:

A. Agrometeorological characterization products, such as in zoning and mapping

Agroclimatic zoning (characterization) is most simply seen as the division of an area according to the favourability for agriculture: the separation of taxonomic agroclimatic units (belts, zones, districts, regions) which differ in climatic resources. Characterization methods generally distinguished are: general agricultural suitability; choice of crops, varieties, growing seasons; soil-climatic zones for cropping (systems); disaster susceptibility; flexible crop planning, coping with risk and uncertainty; improvement in crop productivity; assessment of potential productivity; exploitation of agroclimatic resources for specific purposes. Geographic Information Systems (GISs) have successfully focused on capturing, storing, displaying “natural capital” but much more recently also depict socio-economic indexes and variables. Only over recent years, there has been an increasing use of mapping in informing decision makers at the higher levels.

A hot-season crop like sorghum, which can stand temperatures ranging from 15°C to 40°C, performs well if water is not a severe constraint. On the other hand, regions where a mean 10-day rainfall of more than 30 mm is only available continuously for just 30 to 40 days are highly drought prone. Scientists in India advised farmers that, under such conditions, they should grow either grasses or fodder for animals. Similarly, absence of rain continuously for

7 or more days necessitates resowing and/or soil moisture conservation techniques. Comparably, very local information on water deficiencies obtained from local water balance computations were used to delineate areas and seasons with deficiencies, which in turn helped to develop the probable amount of supplementary irrigation needed for recharging the soil at any given period. Such zoning information and recommendations from research support systems have good intentions. However, if agrometeorologists develop understandable maps depicting results as the above on a large scale with a known accuracy, showing the vulnerability of regions for related disasters, then we have a beginning of an agrometeorological service. But even further work is then needed to get that information in a form with which extension workers can institutionally assist farmers at the field level in an educational commitment (Figure 12). Only such services make a difference in the livelihood of farmers, no matter whether the scientists develop maps in a simple way or through complicated GIS.

In the context of the floods in East Java, Indonesia in 2005, appropriate flood risk maps in the areas concerned were freely available on the internet for a few years, but the follow-up actions were missing. The makers of the maps were quoted in the local newspapers saying “they were only the monitoring agents and not responsible for awareness at government level”. While the governments at various levels indicated not to know how to handle such information! If there are policies to reduce the impacts of disasters, they are most often only related to measures in the much later response phase. They should be taken in the preparatory phase by increasing the awareness and preparatory power of people, in that way reducing their vulnerability. That would be services using such flood risk maps.

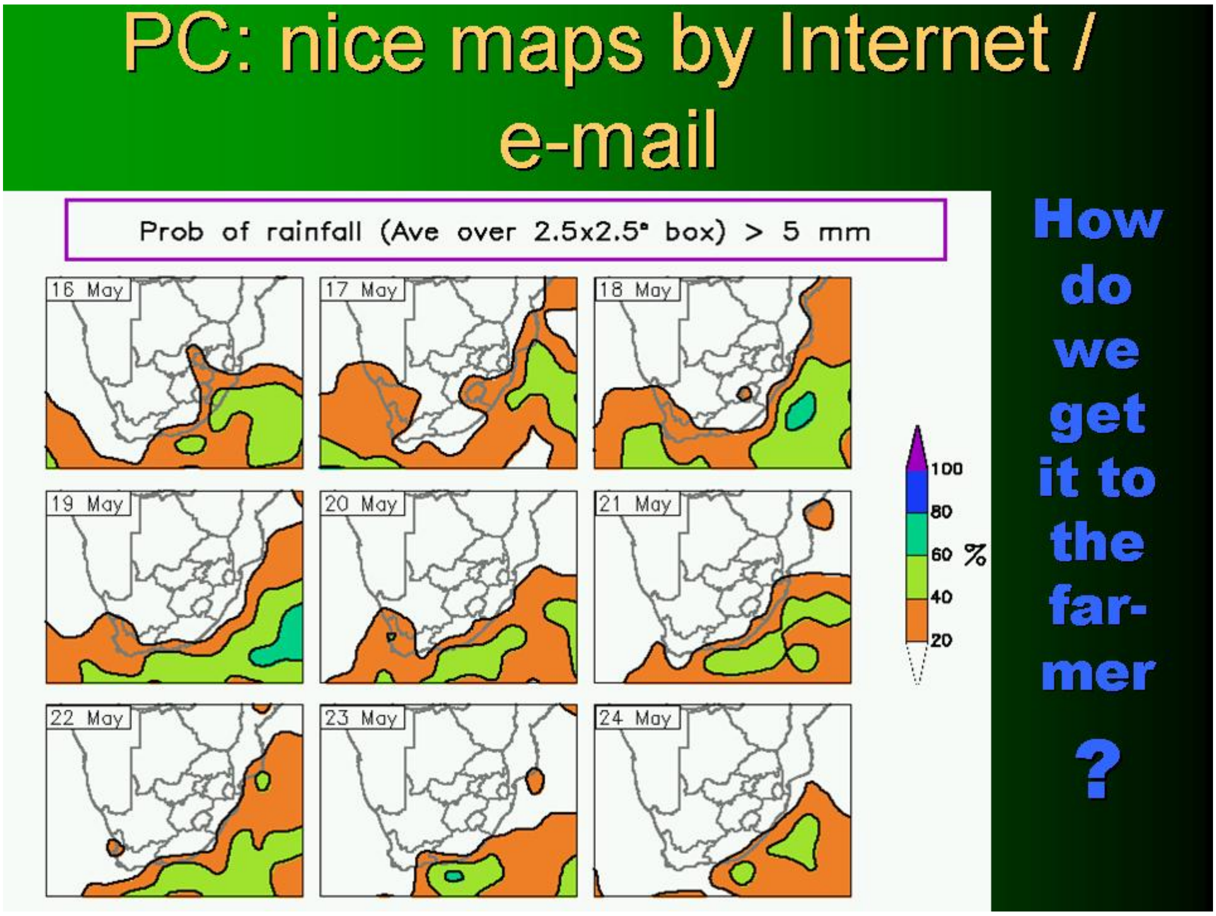


Figure 12. How do we get it to the farmer? [Material by Eduard Mellaart, South Africa]

Maps can indeed be helpful for decision makers of government institutions. Maps from drought monitoring are perhaps most well known in the present agrometeorological literature. The satellite information maps from 1975 and 1985 of Figures 13 and 14, made for the region near the south-western corner of the Gezira irrigation scheme in Central Sudan, close to the White Nile, clearly show particular consequences of advancing desertification. Mobile sand dunes, formed from sand arriving from the Libyan desert, were threatening that irrigation scheme. They were the reason to establish the shelterbelt of Figure 2 as protection. So the agrometeorological service of making such maps would give the opportunity to forestry department decision makers to design and extend such a belt as an agrometeorological service for protection purposes against wind blown sand. The improved design summarized in the introduction was such a service again, belonging to type B.

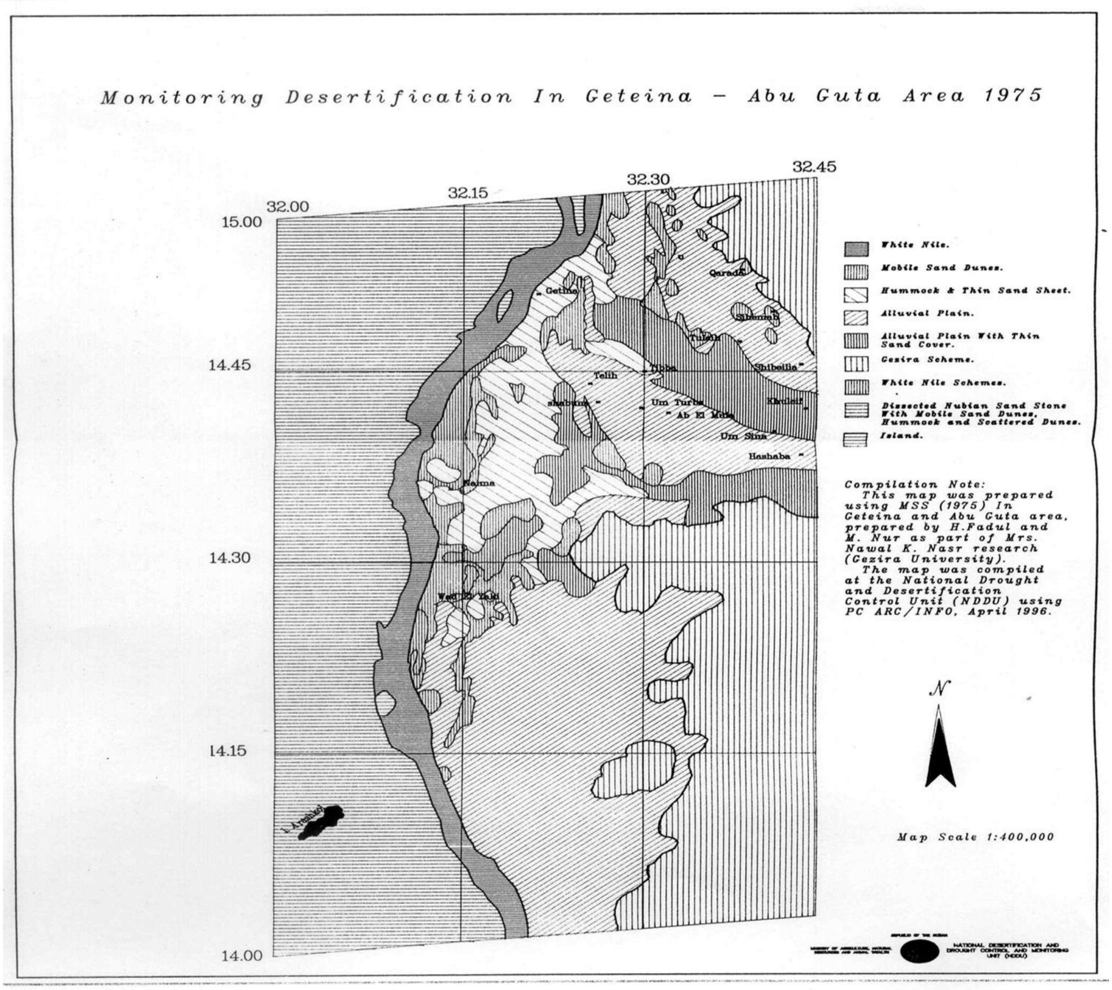


Figure 13. In a Multi Spectral Scanner Satellite information map of 1975, the mobile sand dunes in the upper right hand corner are still at a distance from the Gezira Irrigation Scheme in Central Sudan.

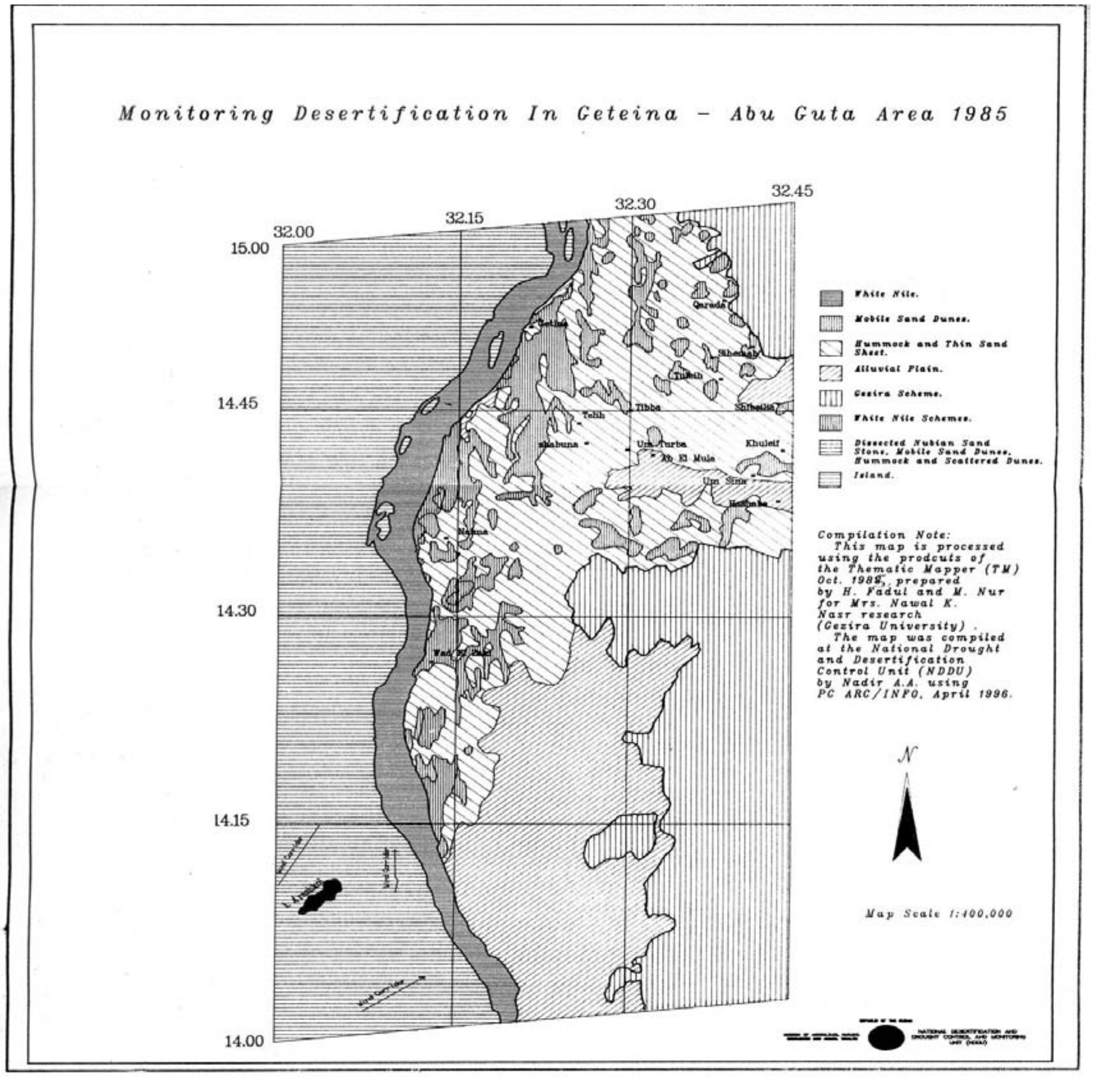


Figure 14. Ten years after the map of Figure 13, a Thematic Mapper Satellite information map shows that by 1985 mobile sand dunes in the upper right hand corner had reached the Gezira irrigation scheme.

B. Advice on design rules for above- and below-ground microclimate management or manipulation

This applies to any appreciable microclimate improvement: shading, wind protection, mulching, other surface modification (such as in irrigation, that may also be seen as a form of mulching, and in drainage, water conservation and harvesting, opening up of crop space), drying, storage, frost protection etc. Examples may already be found in the introduction. Another one is the improved design of traditional underground pits (shallower but wider pits, use of chaff as insulation material around the grain and filling clay soil cracks till 1 m around the pits) in the most suitable clay soils for sorghum grain in Central Sudan (Figure 15). This way the safe storage periods are extended. The research requested by the government was prompted by scenarios of climate change.

In recent weather- and climate-related educational meetings with farmers in Andhra Pradesh, India, funded by WMO and local institutions, virtually in each village the farmers had questions and/or got advice on microclimate issues. It shows the importance of this kind of agrometeorological services. The following matters were handled with the farmers in demonstrations or other discussions:

- soil moisture conservation or drainage techniques (as manipulations) to diminish yield reductions in crops at different stages that either will suffer from rain or need it (the "Onion-Bengal gram problem" in Chandur Village);

- changing the moisture conditions around stored rice still in the husk by spraying it with 2% common salt (as manipulation) that absorbed the moisture and kept the conditions at the seed's surfaces such that premature germination (spoilage) due to rain was virtually prevented (in Yemmangandla Village);

- sun drying of groundnut pods (as microclimate management technique) to protect kernels from being affected by aflotoxins and to improve seed quality (in Loddipally Village);

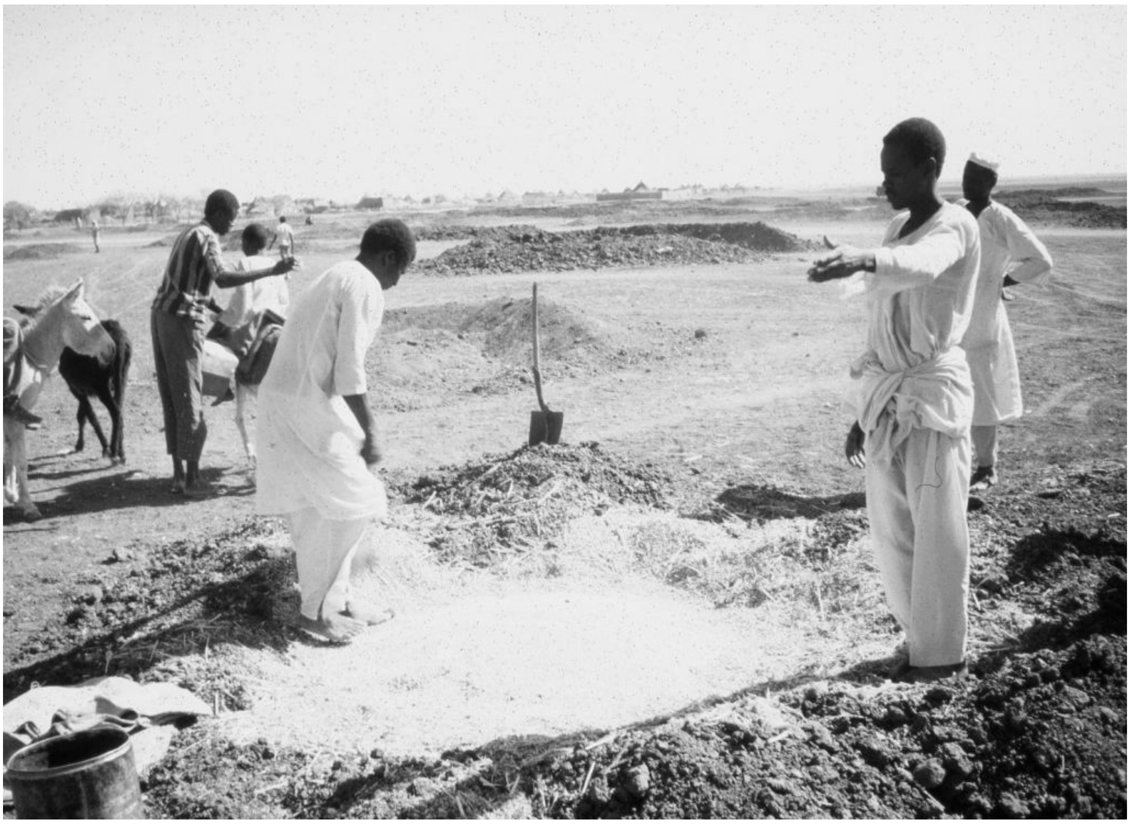


Figure 15. Improved underground storage of sorghum grain in clay soil in Sennar, Central Sudan. [Photo Kees Stigter]

- weather based top dressing of fertilizers (as microclimate management technique) to diminish financial losses and air and soil pollution when using fertilizers unnecessarily (in Vuyyalawada village);

- reduction of red gram crop density (as microclimate manipulation technique) to achieve optimal yields because sparse crops did better under more rain than normal (in Siddaramapuram village);

- soil moisture conservation techniques, where abundant rain is needed in growing orange trees on red soils and improved drainage techniques were little rain is needed to grow them on black soils (both as manipulation techniques) (in Krishnamreddipally village);

- various storage and staking structures (Paddy Bins, as microclimate manipulation techniques) to protect produce from weather risks and uncertainties like tropical cyclone rains, heavy winds, excessive air humidity etc. (in Dendulur village);

- tying up of sugarcane crop to protect the crop from tropical cyclone winds (as microclimate manipulation technique) (in Gopannapalem village, Figure 16);

- rain water harvesting (as microclimate manipulation technique) for vegetable crops (in Kandukur village).

Figure 16. Tying up of the sugarcane stems/culms with dried leaves for protection against cyclonic winds in Andhra Pradesh, India [Photo V.R.K. Murthy]

BOX 5: INSAM CONTESTS - BEST EXAMPLES OF AGROMET SERVICES

From 2005 till 2007, the International Society for Agricultural Meteorology (INSAM, www.agrometeorology.org) held an annual contest with prizes on best examples of agrometeorological services. With 2, 7 and 11 submissions in 2005, 2006 and 2007 respectively, this contest has had some success in getting such examples known and appreciated by more agrometeorologists. For the submissions a protocol form (Table 3) was used that makes it possible to obtain detailed information on the example, its collection and the role it has played for decision makers and ultimately farmers. For 2005, the first prize was the Camaguey, Cuba drought early warning example in the introduction of this report. The irrigation scheduling organization advice example from the Alentejo Region in Portugal under category D of the examples section of this report came second. In 2006 and 2007, first prizes went to Sudan, for the quantitative wind and sand movement research that led to the shelterbelt design (Figure 2) and tree/bush/grass establishment advices combating sand encroachment ("guiding wind, sand and people") near the Gezira irrigation scheme, as explained in the introduction. In 2006, second prize went to design work on improved traditional underground storage of sorghum grain near Sennar, Central Sudan (Figure 15), as briefly described under category B in the example section. Third prize that year went to intercropping research leading to designs of improved traditional rainfed millet/cowpea and sorghum/millet/cowpea intercrops in northern Nigeria. It is shortly described in the examples section under category J. These 2006 and 2007 examples were all based on thorough quantitative on-station and on-farm field research under very difficult conditions in Africa. In 2007, second prize was awarded to an agrometeorological service for irrigation advice in Villa Clara, Cuba, as described in some detail again under category J in the examples section. In 2007, third prize went to a frost forecasting service for agriculture just recently developed in Inner Mongolia (western China) that may be seen as another response farming type (examples section under category C). This submission gave the following description: "On September 10, 2006, in the early morning, a farmer, Mr. Gao Qinglin, felt the cold when he went outdoors. He saw that the water he splashed on the yard the previous day had become ice last night. He realized that his crop could have been harmed. The scene made him sad as his almost matured soybean had frozen. The leaves were shriveled up, the whole crop wilted. His 9.3 hm^2 soybean, all his family cropland, was killed by frost. The loss was 6000 RMB (nearly 800 dollars)".

Table 3. Protocol Form in the INSAM contest for the collection of information on a good example of agrometeorological services or other agrometeorological information successfully provided to (or developed by) farmers in general or to (by) specific farming systems. (Designed by Kees Stigter.)

Short name of the example (new item).

A. Country/Province where the example was found.
B. Institute providing the example (with address).
C. Researcher(s) that collected/described this example (with their e-mail addresses).
D. Field(s) of Agrometeorology to which this example belongs.

[Use the fields of interest defined for registration of members of INSAM.]

E. Natural disaster(s) and/or environmental problems to which the example is related.
F. Way, in which the example was found, defined and collected.
G. Farming system(s) in which the agrometeorological service is applied or to which the agrometeorological information is provided for actual use.

H. Regions of the county (or counties) where the example can be found.
I. Villages where the example can be found.
J. Description of the good example of operational agrometeorological services (maximum of one page A-4), with emphasis on agrometeorological components of the problem(s) concerned.
K. Success and advantages of the example as judged by farmers concerned, where possible also expressed as estimated increase in income due to the services or information.
L. Difficulties encountered in introduction and use of this good example of agrometeorological services or information.
M. Difficulties of the service or information as seen by the farmers concerned.
N. Improvements envisaged or wanted/proposed in the service or information by the farmers, and the feasibility of such improvements.
O. Chances of expanding the application of the improved example.
P. Related examples found elsewhere in the Country (or Countries for that matter).
Q. Do any research results exist on this service/information or on the agrometeorology from which it was derived?
R. Could research assist in improvement of the service/information and how?
S. Any other comments from the collectors of this example that can help in understanding the many aspects of such services/provision of information.

C. Advisories based on the outcome of response farming exercises

As already indicated in the introduction, the time period of advisories spans the growing season from sowing window to harvesting time, and uses knowledge of the recent past as well as forecasts, where available. Attempts have been made in early recognition of seasonal rainfall patterns but they have not been reported as operational information used by NMHSs. The seasonal outlook format (see also under category F) is illustrated in Figure 17. The limitations are clear because the form is probabilistic and only indicates likelihoods for “above normal”, “normal” and “below normal” rainfall for large regions. Downscaling and increasing confidence levels of such forecasts are highly necessary. Also ways have to be found to improve their understanding and use by decision makers at each level.

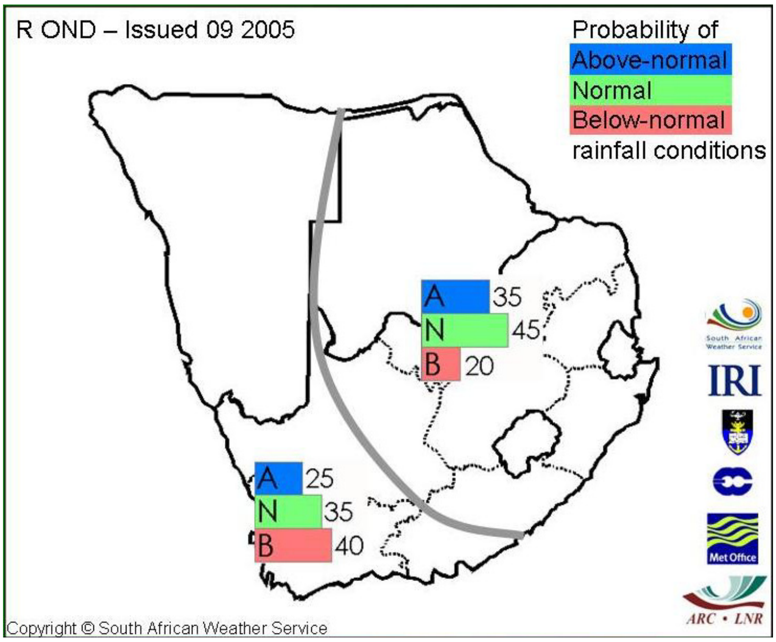


Figure 17. The seasonal outlook for rainfall for southern Africa for the last quarter of 2005. This illustrates the form in which such forecasts become available, with its limitations for use with farmers. [Courtesy South African Weather Service and Eduard Mellaart]

In 2007, in order to make it possible to organize protection from frost, the meteorological bureau of the Inner Mongolia Autonomous Region (north-western China) published for the first time a detailed frost forecast in the whole of the autonomous region. It listed the average first frost appearance time, and gave the forecasted date for 2007 (Table 4). At the same time, the publication pointed out the damage of frost and gave defense suggestions. This included adopting irrigation, making fire to produce smoke in the cropland, and sprinkle against frost for protection, this way mitigating the damage from the frost. The forecast was sent to all sub-regions that subsequently published the frost forecast at their level, based on the provincial forecast, or they used the provincial forecast as their own. They reissued this to the local level government and agricultural departments, while these departments notified the next level department to do the protection work. At the same time, provincial levels broadcasted the frost forecast through TV, radio and news paper and gave protection suggestions. This was repeated at lower levels (also see Box 5.)

Table 4. Initial frost date forecast of Inner Mongolia in 2007 (Example provided by Wei Yurong, Inner Mongolian Bureau of Meteorology, China.)

Area		Initial frost date
Hulunbeir	Pastoral area	1 to 5 September
	Farm area	13 to 17 September
Xingan league		15 to 20 September
Tongliao municipality		23 to 27 September
Chifeng municipality	Northern	13 to17 September
	Southern	23 to 27 September
Xilingol league	Slanting west	25 to30 September
	Slanting east	5 to 10 September
	Centre	10 to15 September
Wulancabu municipality		10 to15 September
Hohhot	Downtown	20 to 25 September
	Northern	10 to15 September
	Southern	23 to 27 September
Baotou	Downtown	23 to 27 September
	Northern	23 to 27 September
	Southern	13 to17 September
Erdos municipality	East	23 to 27 September
	West	23 to 27 September
Bayannour municipality		25 to 30 September
Wuhai municipality		3 to 7 October
Alasan League		3 to 7 October

In Hyderabad, Andhra Pradesh, at the Acharia N.G. Ranga Agricultural University, a form of response farming was developed and tested that now needs funding as a village training commitment for farmers. This includes: a) previous 30 days newspaper cuttings with information on weather; b) traditional astronomy related weather almanac locally followed by the farmers; c) village specific relevant information on effects of weather/climate on crops, agricultural operations and animals in all local languages. Examples include: (i) four days of continuous cloudiness result in an attack of paddy stem borer; (ii) drying of groundnuts in the sun results in eradication of aflotoxins; (iii) animals and harvested produce must be urgently moved to safer places today, due to heavy rains anticipated, because of a tropical cyclone for the next two days, as at present there is a depression in the Bay of Bengal which is likely to intensify further from today noon; (iv) spray fungicide only late in the evenings against the color rot of groundnut and on vegetable crops, because temperatures are likely to increase to over 36° while strong westerly winds are predicted for the afternoons.

Then a “Comparison Concept” first takes into account the weather/climate forecast issued in real-time with its derived parameters as the basis for prediction. This is subsequently compared with the scenarios of past seasons or years. A suitable set of common similarities on levels of pest and disease incidences and crop performance is also derived. This information helps to produce future scenarios of occurrence of pests and diseases, crop performance etc., in addition to determining the levels of incidence of pests and diseases and projected crop yields in the ongoing season. As widely proposed in LEISA, collected traditional knowledge of farmers is finally blended with these weather and climate change response techniques, which will make the farmers even deeper involved.

D. Measures reducing the impacts and mitigating the consequences of weather and climate related natural disasters

Several simultaneous approaches with agrometeorological components currently exist to diminish the occurrence and decrease the seriousness of flood disasters for agricultural production. Protecting and restoring soil cover and blocking runoff water by all possible means, to diminish and slow down runoff, is the best known method in places where hilly areas have to be exploited due to lack of land. Green belts are known to reduce the impact of flooding, and beneficial vegetation in flood-hazard areas and/or upstreams is preserved or improved by reforestation or by erosion and flood preventing growings of grasses and trees/bushes on hill slopes and terrace raisers. Kenyan work on hedgerow intercropping on well-tilled sloping land proved successful but suffered from yield losses due to competition between crops and hedges which should be minimized. Designs of such improvements at institutes with an extension component are agrometeorological services (Figure 18).

In order to get a better basis for soil and water conservation measures, tracking and quantifying soil erosion patterns in the field in simple ways is a more recent approach in farmers’ fields from which services could be derived. The next step is to increase the resilience of farmers with measures that diminish yield disasters from floods and to protect from degradation the agricultural resource base needed for a sustainable agriculture that often uses low to medium inputs. The lessons learned from very exemplarious villages in India suffering a super tropical cyclone formed three categories: livelihood-focused support, participation and community perspectives. Where the lack of natural and artificial drainage causes large areas in India and elsewhere to suffer from water congestion due to high rainfall, flat topography and poor water transmission characteristics in the soil profile, surface and sub-surface drainage have been proven to create yield improving solutions. Other examples come from Zimbabwe, Brazil, Portugal and again India. The most obvious improvements are flood water detention and flood diversion attempts for agricultural purposes. However, if crops are flooded, outlets and drainage have to be provided. One should use crops that can tolerate long periods of complete water saturation. Because crops appear less affected when there is a slow continuous passage of water than if water is stagnant, such conditions should be created as agrometeorological service.

To combat drought and to assist water use efficiency, since 1999 an Operational and Technological Irrigation Centre in Portugal takes advantage of ICT (information and communication technology) potential for information services to support farmers in their irrigation decisions. They provide as an agrometeorological service a web decision support system based on weather stations, most common soils of the region, crops, technologies, and user data. The farmers' irrigation needs can be obtained on line, in real time, if the users input their own water supplies. Multiple dissemination methods are used: internet with a web interface; internet with a personal digital assistant; and mobile phone with SMS messages. The consequences of climate change will be shown by the records over time and may also be predicted.

Figure 18. Hedgerow intercropping design on sloping land at ICRAF (now World Agroforestry Centre) experimental fields in Machakos, Kenya. [Photo Kees Stigter]

E. Monitoring and early warning exercises directly connected to such already established measures

Monitoring and early warning must assist to reduce the impacts and mitigate the consequences of weather and climate related natural disasters for agricultural production as discussed under category D. Agricultural drought is best defined for monitoring purposes as a situation in which crops fail to mature due to insufficiency of soil moisture. Drought monitoring in the case of field crops can be done using the relationship between water use and productivity. For example, the Water Requirement Satisfaction Indexes indicate in percentage the extent to which the water requirements of an annual crop have been cumulatively satisfied at any stage of its growing period. The index at the end of the growing season will reflect the cumulative stress endured by the crop through excess and deficits of water and is closely related to the final yield of the crop.

But the related advice to the farmers should not be lacking. There are several ways of monitoring and forecasting drought but these exercises should always be accompanied by recommendations like growing a short-duration crop, crop thinning, in-situ moisture conservation, etc., as agrometeorological services. As long as farmers do not get validated benefits out of the above advice, monitoring and forecasts only remain support systems actions. The drought monitoring and early warning case studies that have recently been given in the 2006 WMO publication entitled “Drought Monitoring and Early Warning: Concepts, Progress, and Future Challenges” also make that abundantly clear. Improved drought monitoring is mentioned there as a key component of a drought preparedness plan and a national drought policy. Early warning systems can provide decision makers with timely and reliable access to information on which mitigations can be based (Figure 19).

Weather systems monitoring, rainfall monitoring and river flow monitoring for agricultural and other purposes as well as related early warning approaches are playing a role in warning (and therefore preparing) farmers as well as inhabitants of urban areas of floods. Although there is much potential support for giving priority to their implementation, even when followed by advice on the use of that information they have obvious limits in mitigating the consequences of such disasters without improved risk assessments. In a recent paper on growing risks of climate change, it was indicated that the latest planning guidelines in England still allow development in flood hazard areas. They still allow new building in flood plains. Also developers are still permitted to connect foul and surface water drainage to existing drainage systems, even if they do not have sufficient capacity, and sustainable drainage development is still in its infancy with no robust arrangements for maintenance. This indicates that the policy environment, as provided by services, should come before the technical aspects. This is in line with recent recommendations of a Canadian panel of experts in a report on managing flood hazard and risk, among others stating that in Canada “monitoring” and “enforcement of policies and programs” in floodplain land use must be strengthened, in association with flood risk mapping.

Figure 19. Water reservoirs and application of mulches to mitigate drought consequences in Jamaica. [Photo Donovan Campbell]

F. Climate predictions and meteorological forecasts

This category of services applies to agriculture and related activities on a variety of time scales, from days to weeks to seasons to years, and from a variety of sources. Governments, development organizations and other entities spend billions each year on programs aimed at improving the lives of poor people in developing countries. But have these interventions actually made a difference? That's difficult to answer, according to the International Research Institute for Climate and Society, Columbia University, because many programs have not been rigorously evaluated. "Under what conditions do farmers use climate information, such as seasonal forecasts and rainfall trends, and what policies make climate information most effective in improving livelihoods under different types of conditions?" These are the kind of questions that are currently being asked. Conducting impact evaluation in situations in which climate influences the impacts of a particular project presents special challenges. Ideally, one would need to compare farmers' livelihoods when farmers use the climate information and when they do not, over a long period of time. Of course, waiting long periods of time is not useful to policy makers, who need to make decisions in the short term. For the evaluation, one would need to make do with a few seasons of observations perhaps, and available historical records. The fundamental question here is, "*How can we project what the effects of the intervention will be in climate scenarios we have not observed?"*

BOX 6: CLIMATE PREDICTIONS

The success of long-lead El Niño and La Niña forecasts in North America has led to enormous interest in seasonal prediction worldwide, including in developing countries, and has led in many instances to unrealistic expectations about them. The fact remains that climate predictions have at best modest skill, and in many circumstances no or marginal skill, in the absence of a strong ENSO signal. Nevertheless, it has been argued forcefully by a number of groups that these sets of forecasts have tangible economic value for a class of decision-makers and users. The credibility of the arguments depends on whether real decision-makers and users behave in the manner assumed in the models. Estimates of the uncertainty in forecast value for different forecast skills and realistic iterations of the forecasts/decisions have been made, with different simple assumptions about the psychology of the user (for example, the user abandons use of the forecast if the forecast was wrong two winters in a row). The computed uncertainties cast considerable doubt on the utility of marginally skilful forecasts sets for individual users and provide a sense of what skill levels are necessary to increase likelihoods that relatively short sequences of forecasts/decisions will be of value. These skill levels turn out to be relatively high, comparable to the performance of the strong ENSO event "forecasts of opportunity." Including again the presently most common form of these forecasts as illustrated in Figure 9, care should be taken that this agrometeorological service tool is not overestimated by wishful thinking. Many more case studies should be collected on actual attempts to use such forecasts and in what form this has been successful for which target groups of users under what conditions. This will assist in the needed improvements of successful production and use of seasonal and other long term climate predictions.

The early seasonal climate forecasts on drought in Ceará, N-E Brazil, for maize/bean/manioc growers, were found by Lemos and colleagues to be a disaster. An emerging technology "was appropriated and pressed into service of a policy making apparatus designed to reduce the impacts of severe droughts." Policy makers started to exaggerate the potential usefulness of the science product, "therefore creating a situation of cultural dissonance between science and local knowledge and belief systems that quickly eroded the value of the information". The scientific product was not used to lead to useful agrometeorological services. Due to their particularly vulnerable socio-economic conditions, the farmers were unable to respond to raw climate predictions, irrespective of the quality and the precision of the forecasts.

An example of an organizational context in Africa was shown in 2003 when the Drought Monitoring Centre of Nairobi was changed into the Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (ICPAC) in order to reflect better all its new mandates, mission and objectives. One of its three objectives is to improve the technical capacity of producers and users of climatic information, in order to enhance the input to and use of climate monitoring and forecasting products. Its mission is described as "fostering sub-regional and national capacity for climate information, prediction products and services, early warning, and related applications for sustainable development in the IGAD Sub-Region". The recent past climate over the Horn of Africa is provided through decadal, monthly and seasonal summaries of rainfall and drought severity and monthly temperature anomalies. The current state of climate is monitored and assessed using climate diagnostics and modelling techniques. These are derived from information on the state of the sea surface temperature anomalies over all the major ocean basins, surface and upper air anomalies of pressure, winds and other climate parameters.

The prediction products are provided through outlooks for a decade, month and season. Consensus pre-season climate outlook fora are also organised in conjunction with the major climate centres world-wide in order to derive a single consensus forecast for the region. An assessment of the vulnerability together with the current and potential socio-economic conditions and impacts (both negative and positive) associated with the observed and projected climate anomalies is also made on decadal, monthly and seasonal time scales. These products are disseminated to all NMHSs of the participating countries to serve as early warning information to a variety of sectoral users of meteorological information and products including policy makers, planners, health, energy, agricultural and water resource sectors, farmers as well as research institutes among others, where they can be used to establish services (see again Figure 17).

G. Development and validation of adaptation strategies to changes (such as in climate)

This category of services involves adaptation to increasing climate variability and climate change and other changing conditions in the physical, social and economic environments of the livelihood of farmers. If supportive scientists develop with intermediaries and farmers an improvement of an already existing adaptation to increasing climate variability, then the new product may be called an agrometeorological service when the policy environment is conducive to such change. The following two examples from India show what is basically possible to make a positive difference in the livelihood of farmers.

The first is the use of the Southern Oscillation Index (SOI) to advise farmers on growing either cotton or peanuts in parts of India. In years with positive SOI, peanuts outperformed cotton in 70 percent of years and in negative SOI years there was only small advantage in 40 percent of years. So, if farmers grow cotton in SOI negative years, the above supportive research produced a sensible agrometeorological service. The second example is potential advice on the seasonal rainfall probability for profitably growing of peanuts in parts of India. The supportive research results indicate that if the seasonal rainfall (July to December) is >50 cm, the yield probability of >1.5 t/ha is 50 percent and the probability of yields <0.7 t/ha is zero. Therefore, prediction of rainfall "greater than" or "less than" 50 cm would be extremely helpful to the farmers. However, it appears that in 87 percent of El Niño years the seasonal rainfall was <50 cm, but of the 58 years with rainfall <50 cm, only 21 were El Niño years. This shows the problems of supportive research to develop services. Still, a better forecast would be if this information was reliably explained as probabilities, and was made available in time and in a way that local farmers can absorb, and if other agrometeorological information and other inputs for crop production could be simultaneously supplied as per the required schedules.

The passage of Hurricanes Hugo and Gilbert in the late 1980s fueled a turning point and focused the attention of policy makers in the Caribbean and the international community towards the importance of investing in improving the capacity of the countries in the region to mitigate the effects of these events. As a result, government policies must address strategies to increase the adaptive capacity and responses of farmers. Farmers in St. Elizabeth, Jamaica, need help to adapt to these changes within their environment. Of particular importance is an understanding of farmers' response to these events before, during and after they occur. In recent years, Jamaica has again been seriously affected by a number of extreme events. Hurricane Dean passed along the south coast of the island in August 2007, damaging crops and disrupting livelihood activities for many small farmers. Adaptive strategies employed by farmers to reduce damage to their farming systems were documented in the immediate period of Hurricane Dean. By doing this, the positive correlation between farmers' perceptions of hurricanes and the degree of damage to farming systems was highlighted. Secondly, through an analysis of socio-economic and environmental data gathered, an understanding was reached of the determinants of adaptive capacity and strategy among farmers in the area. Employing assets available to them, farmers in southern St. Elizabeth have demonstrated a number of damage-reducing strategies to lessen their exposure to Hurricane Dean. The study shows that despite high levels of vulnerability, farmers have demonstrated that successful adaptation can be achieved at the farm level. To help farmers and by extension improve food security in the country, more adaptation options to these climatic extremes need to be made available. An understanding of the perceptions and risk coping choices of farmers will equip policy makers with necessary tools to help reduce the exposure of the sector.

The adaptation strategies most valued in the literature, and therefore of importance to agrometeorological services, should be ones that are supported by local research and that focus on educational commitments. One may particularly select the following:

- participatory on-farm validation of new approaches and environmentally sound technologies in agricultural production;

- improved efficiencies of the use of resources and their protection, including those of use and protection of germplasm, soil, water and energy in agricultural production;

- the three following categories of agrometeorological services.

H. Specific weather forecasts for agriculture, including warnings for suitable conditions for pests and diseases

This category of services is focused on the advices on countervailing measures against pest and diseases. There is a considerable loss in the production of food grains due to occurrence of pests and diseases. Supportive studies based on the relationship between the micro/macro climate and origin, multiplication, spread, and intensity of diseases and pests may be useful to understand the environmental conditions that are conducive for their development (see again Figure 1). In the 1960s, the synoptic situations associated with the migration of desert locusts were already identified. In India, early research developed a method for predicting wheat stem rust appearance in South India based on the occurrence of synoptic conditions likely to lead to the transport and deposition of spores. More recently, a forewarning theory was created which has a potential as an indicator of mustard aphid population development. Using simple parameters, this can be done as early as one month in advance. This may enable the farmers to be ready with necessary tools to combat the pest problem, if advised accordingly.

Downy mildew is known as one of the most important vineyard diseases in South Africa's Western Cape province, because it has the capability to develop and spread very quickly, and to cause large crop losses in certain years according to the weather conditions. Farmers must make decisions as whether or not to spray for downy mildew and also how frequently to spray and which agrochemicals to use. Obviously they want to limit the number of times they spray to reduce costs and environmental pollution, but they also want to minimize the risk of crop failure due to infection by downy mildew disease. Already in 1992, an Austrian researcher developed an automatic weather station and associated software, as an agrometeorological service to predict the occurrence of primary and secondary infection of downy mildew. However, this model was not sensitive enough to accurately calculate infections in South Africa, and furthermore it only gave a "Yes/No" warning of possible primary and/or secondary infections. As a form of agrometeorological service, the software model was adapted for South African conditions in 1995 and 2006 to make it more accurate and user-friendly. This model output now provides a graphical representation of the past weather variables (up to 3 weeks), and an indication (3 different colors - high, medium and low chance) of possibly favorable periods for both primary and secondary infection occurrence.

I. Advices on measures reducing the contributions of agricultural production to global warming

This category of services includes keeping an optimum level of non-degraded land dedicated to agricultural production. Until the 20th century, agricultural land was devoted to food production, and managed separately from lands for other uses such as urbanization, industrialization and infrastructure. Since then, the explosion of population, coupled with heavier industrialization and urbanization has considerably increased competition for land, resulting in fragmentation of agricultural land parcels, as well as direct loss of land. These processes are expected to continue in most industrialized countries into the foreseeable future. In developing countries such tendencies also occur as, for example, what may be witnessed on the island of Bali with respect to the tourism industry. In these countries agriculture had also to expand into marginal lands, with concurrent loss of pasture and forest lands and considerable expansion of land degradation. These changes in land use have had large impacts on global warming.

This is the only one of the ten categories for which examples are shown where one may not yet expect agrometeorological services to have been developed in developing countries. The argument is gaining ground that win-win situations do exist in which developing world farmers will make profit from changing into processes with reduced greenhouse gas emissions or increased carbon sequestration. Simply not burning plant residues and burying them instead is propagated by many extension services because of the resulting soil improvements but not with regards to greenhouse gas reduction. The Clean Development Mechanisms are supposed to be win-win situations in which the local argument is the money earned while the donor argument is related to atmospheric aspects.

However, for the time being agrometeorological services of this kind may be expected to be argued in the high-tech agriculture of the western world. What follows are some ideas for the future in cases where we are succeeding in getting improved agriculture adopted by more farmers in presently poorer societies.

In recent literature, the following topics have been reviewed: the development of agriculture and land use change; the interactions between physiological properties of vegetation, ecosystem properties and climate; the impact of agriculture on weather and climate; the interactive mechanisms resulting from human activities; strategies for obtaining more relevant greenhouse gas data; and strategies for promoting management practices to reduce the impacts of agriculture on climate. The most relevant recommendations from this review with strong agrometeorological components were:

- to ensure a more comprehensive consideration of agricultural systems in modeling, to quantify past and current impacts of agriculture on climate, considering that agricultural activities cover more than one third of the earth's land resources. The objective is to improve knowledge of atmospheric components resulting from agricultural activities (gasses, aerosols, dust, particulate matter, etc.) and their impact on weather and climate;

- to encourage the development and adoption of national policies to ensure food availability, security and safety, and to promote land management methods such as agroforestry and modified rice growing in order to preserve the local, national and global environment;

- to prevent submergence of rice fields wherever feasible without affecting the rice productivity; increased adoption of direct seeding instead of transplanting; crop diversification in rice-based cropping systems; water management by intermittent drying and mid-season drainage in controlled water situations; growing rice cultivars having traits with low methane emission potential; use of sulphate containing fertilizer; minimizing soil disturbance during the growing season to reduce the escape of entrapped methane; and use of properly composted organic amendments. Several of these measures also serve resource-use efficiency purposes in a win-win situation.

- to promote strategies by the agri-food and animal production community and NGOs to reduce greenhouse gas emissions from livestock by better matching feed characteristics to the nutritional needs of the animal and by adopting and applying manure management techniques with strategies to facilitate the absorption of better management practices for optimal application of N fertilizers. This should be achieved without negative environmental impacts while improving economic return of organic wastes and nutrients by application to agricultural land, controlled digestion and biogas methane recovery, and promoting solid rather than liquid handling of animal manure.

J. Proposing means of direct agrometeorological assistance to management of natural resources

This category of services is meant to be in the context of development of sustainable farming systems in technological advances with strong agrometeorological components. The following are examples with water, trees and multiple crops on arid soils as natural resources.

An agrometeorological service for irrigation in Villa Clara, Cuba helps producers to achieve proper use of water resources and aims to allow users to manage that water efficiently, giving the plant enough water in a timely manner. The agrometeorological forecasts are constructed from weather forecasts in the short and medium term and the expected trends in climate forecasting of monthly rainfall and temperatures, taking into account the local history of the behavior of the elements predicted. The outputs of the service are:

I. Estimation of the weekly water needs of crops.
II. Evaluation of the state of operation of irrigation equipment.
III. Monitoring results of the response of field crops to recommended irrigation.
IV. Availability of agrometeorological data.
V. Information collected on irrigation.

The information is provided from the weather stations to the Meteorological Center, and then transmitted directly to all the specialists and farmers by the local radio stations at coordinated times. The service is not only used by specialists or those in the units responsible for the irrigation of agricultural production. It is also used by government authorities, such as in councils or watersheds, and environment management officials from any territory. This service has been brought into operational practice from 2005 and unexpectedly the supplied information is not only used directly for irrigation purposes, but it is also widely used by farmers near towns for other water management aspects.

Intercropping components adopted by farmers in northern Nigeria are grown at low densities, to minimise risks and exploit resources in a good cropping season (Figure 20). High year-to-year variability of rainfall, serious deep percolation and high soil evaporation losses are additional stresses. When the rainfall was below normal, the intercropping systems showed better water use efficiency than all mono-cropped systems, with the exception in the case of sole millet with inorganic fertilizer side dressing, due to millet dominance exerted by earlier planting and heavy tillering. Both cropping systems were rooted beyond 1m in the loose sandy soil. Sorghum root production was greater than for millet, while both cereals produced greater root densities than cowpea. The overlap of the roots of component crops suggests competition for resources. Cowpea produced greater root densities and achieved deeper rooting when intercropped with millet and/or sorghum than mono-cropped, suggesting adaptation and competitive ability under intercropping. Rooting depths of crops were shallower in a relatively wet season than when water was limiting. Root densities and proliferation of the cereals below the surface layer were much higher in low fertility soils than when nutrients were readily available. An answer with designing improved cereal/legume intercrop systems in the Nigerian arid and semi-arid zones should include genetically superior crop cultivars and the manipulation of the component densities along with the improvement of microclimatic variables. An amelioration of the traditionally preferred rainfed millet/cowpea and sorghum/millet/cowpea intercrop systems may involve a reduction in plant density of the tillering and faster dry matter accumulating millet component, while the low growing and ground covering cowpea component density is increased. The results indicate that abundant organic manure in combination with agrometeorological services of microclimate improvements by intercrop manipulations may control near-surface land degradation in northern Nigeria under acceptable sustainable yields.

Expectations for hydro-climatic research have changed, such as those involving forests and large amounts of scattered trees, as the contract between science and society has evolved to require that researchers provide “usable science” that can improve resource management policies and practices. However, decision makers have a broad range of abilities to access, interpret, and apply results. Should research programs aim for efficiency and target high-end users? Should they aim for impact and target decisions with high economic value or great influence (e.g., state or national agencies)? Or should they focus on equity, whereby outcomes benefit groups across a range of sophistication? Consideration of equitable access to information led to the creation of a series of user-centered knowledge development tools for seasonal hydro-climatics, available over the Internet. Recognizing that many individuals lack Internet access, the design for these web tools also includes capabilities for customized report generation, so extension agents or other trusted information intermediaries can provide material to decision makers at meetings or site visits (Figure 21).

DETAILED ORGANIZATION

After presenting the ten categories of agrometeorological services, one needs to deal with how to institutionally connect the establishment of these services with better development of farmers’ livelihoods in rural areas that experience an improving “services culture” (e.g. Box 3). This is a first institutionalization in rural education. What has recently been better understood is indeed the need for such new educational commitments towards farmers. The material of all the boxes in this report is tied together here. Response farming in its widest sense will be an important issue in the establishment of agrometeorological services. Above we have given it its place, also showing elements of it in other services. Educational commitments that have recently been tried out, in addition to the still often failing classical agricultural extension, were among others Response Farming Advisory Teams (such as in the Mali Pilot Projects), new Roving Seminars for extension personnel or extension intermediaries or farmer facilitators or farmers themselves (such as for agrometeorology those of ANGRAU in India, WMO in West Africa, Ethiopia, Sri Lanka, and Bangladesh and Agromet Vision in Iran, India, South Africa, Indonesia, Lesotho, Swaziland, Brazil, Argentina, Zambia and Zimbabwe), Farmer Visiting Schemes, Farmer Demonstration Facilities, Farmer Field Days and Farmer

Field Schools (FFSs), including Climate Field Schools (CFSs) (such as those organized in Indonesia).

It has to be realized that such undertakings are often focused on solving certain priority problems identified by farmers, like in the Integrated Pest Management Field Classes that stood at the start of the FFS developments, but some are training the trainers. A most important conclusion is the need for local and national networking that should precede and follow such educational commitments. In addition to the follow-up of the training contents in the educational commitments themselves, this is the second institutionalization without which upscaling of successes will be much more difficult to reach. The FFS/CFS alumni must remain in contact as Farmer Groups, also because the farmer to farmer (or community participative) extension remains one of the most important means of dissemination (such as in Figure 11). Trainers/facilitators/intermediaries need to see each other and their trainers and they should be able to collect feedback from farmers. Curricula have to be further developed, improved and multiplied, and networking is the only way to get that done. Modern communication techniques are ideal for organizing such networking and keeping it going, but rural meetings to exchange experiences face to face are indispensable as well.

Figure 20. Low density intercrops of sorghum, millet and cowpea grown on ridges in northern Nigeria. Access tubes for neutron probes for soil moisture determinations are also visible. [Photo Kees Stigter]

Figure 21. Extension recommended ridges in dry-rice fields intercropped with maize in Gunungkidul, Yogyakarta Special Province, Java, Indonesia, constructed by alumni of a Climate Field School. See also Figure 8. [Photo Esti Anantasari]

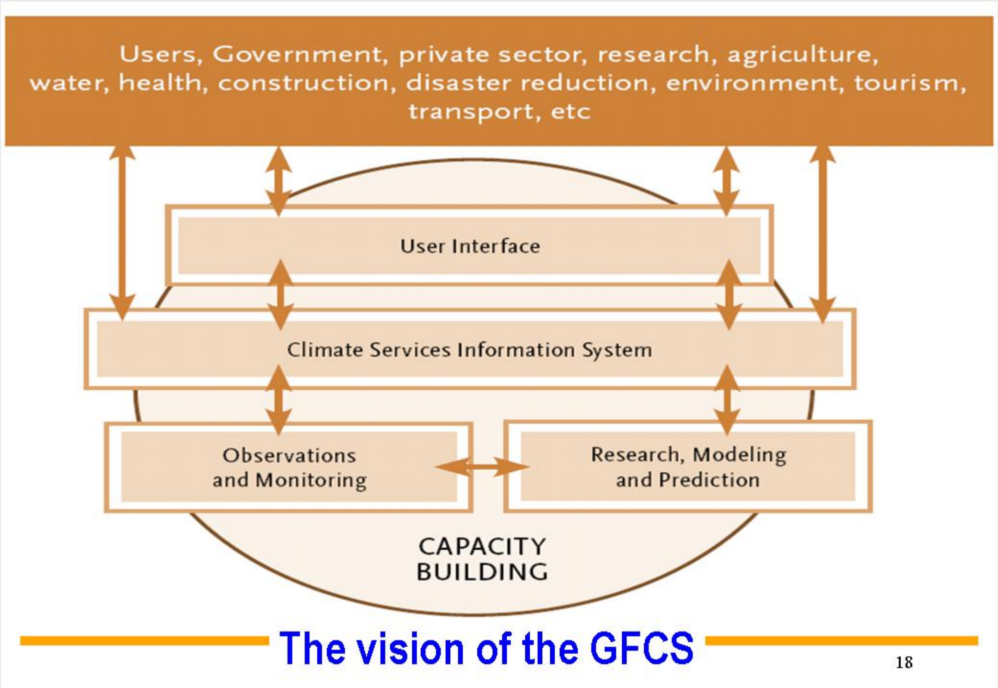
On a global scale, the Global Farmer Field School Listserve (Global-FFS-l), which has been launched as part of the Global Farmer Field School Network and Resource Centre (FFSnet), is a great forum to share results and frustrations, policies and the lack of it. In the context of the present food crisis, background discussions are on (i) a widely felt need to recognize that globally free trade for agricultural commodities will just not work, (ii) that self-sufficiency to the extent that natural resources allow, through engaging very large numbers of small scale farmers, is the best that poor countries can in first instance aim at, where sensible extended to relevant regional trade, but (iii) that this demands expansion of the markets in such ways that the food needs of the poor and hungry are translated into effective demand by special support systems. This is the background against which well organized FFSs/CFSs can further develop from the bottom upwards.

BOX 7: GLOBAL FRAMEWORK FOR CLIMATE SERVICES

In 2009, WMO organized, along with several partners, the World Climate Conference Three (WCC-3) decided to establish a Global Framework for Climate Services (GFCS) to strengthen the provision and use of climate predictions, products and information worldwide. The WCC-3 called upon the WMO to convene, in urgency, an intergovernmental meeting to approve the terms of reference and to endorse the composition of a Taskforce of High-level independent advisors which, after wide consultations sent a report in May 2011, including recommendations on proposed elements for this Framework and next steps, for consideration by the Sixteenth World Meteorological Congress. This Congress, after a thorough and long debate and discussion, established the GFCS.

This GFCS will boost the availability of climate information needed by policy-makers and people to plan ahead and to take decisions that are sustainable in a changing climate. It will be a global undertaking involving a wide array of stakeholders (Figure 23). Climate services are vital to cope with climate risks and seize opportunities, and protect lives and livelihoods, but often do not reach communities which are most vulnerable to climate change. The GFCS should close the gaps in the provision of existing information and services. Its primary goal is to ensure greater availability of, access to, and use of climate services for all countries. Currently around 70 developing countries have little or no climate information. It will serve as a permanent platform for dialogue between providers of climate services (essentially NMHSs) and users ranging from policy-makers to land managers to farmers.

The GFCS promises to unleash the full potential of billions of dollars invested in climate observation systems, research, and information management systems. The GFCS will initially focus on four user communities: disaster risk management, water, agriculture and health. The GFCS will have an User Interface Programme where these communities will be asked to input their needs for better climate information and products. Based on the agrometeorological services described in this report, there are many examples of what kind of information the agricultural community needs and as important there are already examples of how the climate community can solict input from the agricultural community. In some sense, the GFCS has already been started by these agrometeorological services.



Schematic of the GFCS (WMO)

In agrometeorology, there are already some initiatives that have been taken in a first stage of organizing new educational commitments. In 2007, a group of WMO experts met in New Delhi and proposed new curricula for agrometeorology, that were published by WMO in 2009, not only in higher education but also for two kinds of intermediaries. Of the latter, one kind should preferably be staff of NMHSs, research institutes and universities, where agrometeorological and other products can now be made client friendly. These can then be taught to the second kind of (government and NGO extension) intermediaries that should work with the farmers in CFSs. Institutionally, this demands new educational commitments, on a large scale, by the providers of the products (Figure 22) as well as by governments/NGOs. The agricultural extension should be renewed institutionally in approach and contents, both with strong participation of Farmer Groups that will come to the CFSs/FFSs, for new and improved needs assessments. Illiteracy, vulnerability, poverty and a high need for farmer differentiation are initial and boundary conditions of this new approach in educational commitments. External funding promised to Africa and internal funding promised by governments of emerging economies like China, India and Brazil should, among many other priorities, also be used on such institutionalized commitments.

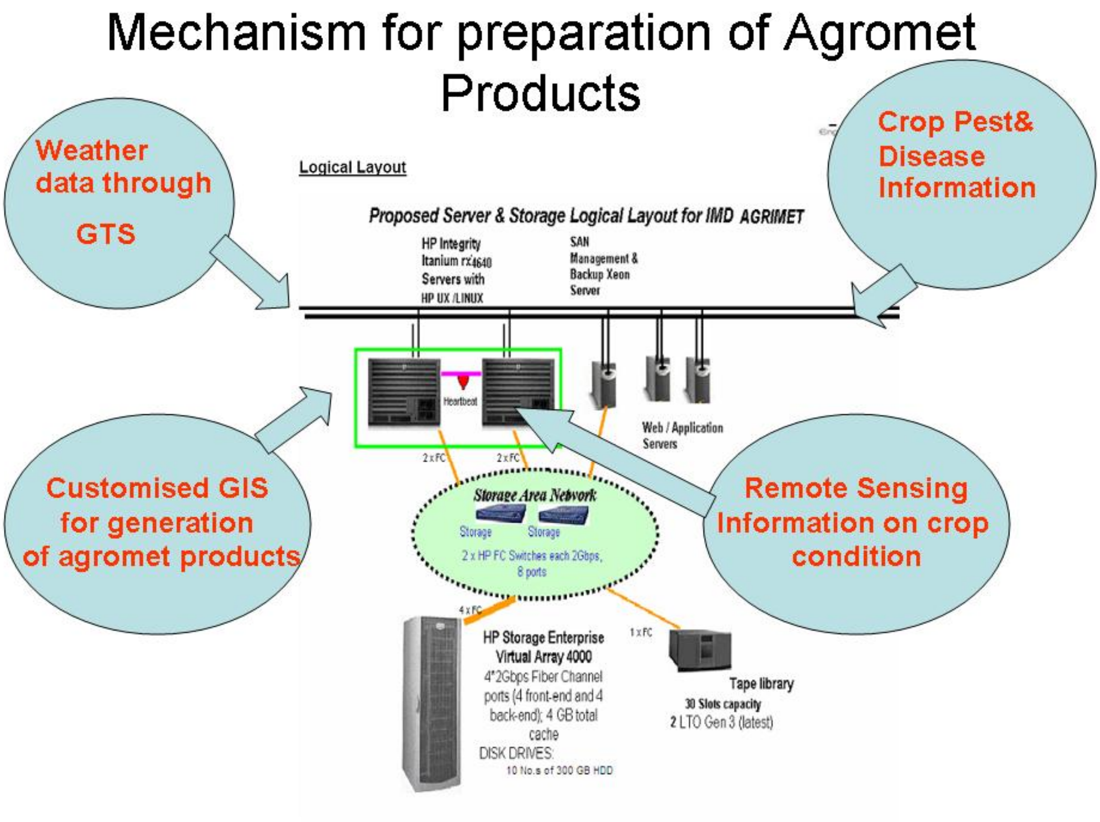


Figure 22. The working steps in the Indian National Centre cover data collection, quality checks, running models and product generation, while decentralized extension offices (AMFUs) utilize the products for establishing the services/advisories. [Courtesy NCMRWF (India)/L.S. Rathore]