II.A Introduction to Part II (INSAM Examples)

Kees Stigter

Of the examples of agrometeorological services for developing countries, distinguished under ten headings as recently reviewed (e.g. Stigter 2008c; WMO 2010), almost all products developed with focused scientific support are just the seeds sown for the development of actual agrometeorological services in an extension approach (Stigter 2009). But we want to get to a situation in which, in a "farmer first paradigm" (e.g. Chambers et al. 1989; Winarto 2007), livelihood problems and farmer decision-making needs can guide the bottom-up design of actual services. Services based on products generated by operational support systems in which understanding of farmer livelihood conditions and innovations have been used (Stigter 2008a). We have developed in the last decade a good idea of what is needed to develop such agrometeorological services from scientific products generated by National Meteorological and Hydrological Services (NMHSs), Research Institutes and Universities (KNMI 2009). But what we need is institutionalization of science supported establishment and validation of such services (Stigter 2009).

Of the examples originally collected in the INSAM contest for the best examples of such services (INSAM 2005, 2007, 2008), some have been institutionalized and some were developed with and for specific target groups of farmers but not institutionalized. These operational services are the best illustrations of what has been institutionalized in some countries and of what is needed to validate those examples and learn from them. While other examples show the missing links with the livelihood of larger groups of farmers (WMO 2010). The writing on these services was done using a procedure developed and accepted for this particular situation (protocol). The contents of these protocols were fully re-edited and updated for this book (List II.1). Below we make intercomparisons and draw lessons on focused supportive research, institutionalization and validation issues, also referring to other parts of this book. The ten categories of agrometeorological services earlier distinguished by Stigter (e.g. 2008c; WMO 2010) are in List II.2.

K. Stigter (✉)
Agromet Vision, Bruchem, The Netherlands; Agromet Vision, Bondowoso, Indonesia; Retired from Wageningen University (Wageningen UR), Wageningen, The Netherlands
e-mail: cjstigter@usa.net

K. Stigter (ed.), *Applied Agrometeorology*, DOI 10.1007/978-3-540-74698-0_2,

In the first protocol of this Part II, on *Design of Sand Settlement of Wind Blown Sand Using Local Trees and Grasses (Sudan)*, one of a large number of services that we developed at Universities in Africa, it follows from our reporting that we indeed remained in the stage of focused scientific support. The category of agrometeorological services to which it belongs is D., the disasters being desertification and wind blown sand. But, as many examples will show, there are often double category services, because here the mode of the combating of disaster as an agrometeorological service belongs also to category B.

This is definitely unique research, an approach that can be of use everywhere in the world where sand encroachment by wind is a serious problem. The quantitative strategy developed in this problem solving is exemplarious and useful data have been obtained under extremely difficult field conditions. But without a serious follow-up by an internationally supported national institute or a specialized international institute on combating desertification, where the possibilities of air seeding at the right moments of the appropriate vegetation is seriously studied, there are no chances that the developments we report on can lead to any actual agrometeorological service as explained above.

We would like to prevent that we get in the same situation as explained under S. of this protocol, where we state that "The kind of design work on holding back the desert, reported here as an agrometeorological service, could also have been carried out on desertification issues that are at the basis of the resource wars that sparked off many of the civil war situations that occurred and are occurring in Sudan. Appropriate international funding of such work should have started in the 1960s and 1970s, 30–40 years ago, but was refused even 10 years ago for example by ISNAR". ISNAR is the Institute for Studies of National Agricultural Research of the Consultative Group of International Agricultural Research (CGIAR). But poor countries with regimes internationally seen as doubtful, definitely when acting towards the people suffering from the resource problems concerned, are now unlikely partners in the development of appropriate policies to carry out the required research and experiments. But very often national research institutes in Africa can be trustable partners that can do a lot without government interference.

We have shown here that with great efforts but relatively little means, field research of high quality could be carried out, in a research education context, that showed the direction in which further progress has to be made. The institutionalization of further research related to such problems looks very far away, the marginalization of people and countries suffering from such problems is most likely to remain. So far we have only sown the seeds for the development of actual agrometeorological services in an extension approach. Emergence of those seeds demands a very different international research environment and a very different international political support environment. Most chances for any future progress nationally we see in China.

The second protocol reproduced here, on an *Agrometeorological Service for Irrigation Advice (Cuba)*, is a typical example of a well institutionalized agrometeorological service, for the time being on the scale on which it was developed. It is also an interesting case of an issue we will come across again also several times below, that is the higher importance of water management improvement and of a gain in water use efficiency of crop growth, compared to low yield increases. Other examples of the same come form places as far apart as China and Sudan. The category of agrometeorological services to which it belongs is again D., the disaster now being drought. But this is again at least a double category agrometeorological service, because now the mode of combating disaster, as an agrometeorological service, belongs also to category J., water being the natural resource concerned (WMO 2010). However, expanding the definition of response farming as we recently did (Stigter 2008d), this may as well be considered an example of category C. (WMO 2010).

If we look at the difficulties experienced, some (such as the lack of agronomic data) are beyond the influence of those that developed the agrometeorological service. But these are issues that can not be described often enough, because they are much more general problems in most developing countries. They very often also prevent good validation attempts on a larger scale. However, other problems met, such as the "synchronization" of relevant radio broadcasts with the working hours of farmers, have also been reported to me from places as far apart as Indonesia and Nigeria. These are solvable problems when brought to light appropriately. And so are poor communications between users and service technicians as intermediaries. This is improving almost everywhere as long as we do not make the socioeconomically wrong choices of technology (Nicholson 2009). It is interesting to also note here the remark on the necessity of a minimum of such field technician intermediaries.

With increasing availability of these useful services as a main goal, this is an issue of successful institutionalization that we will come across several times in the protocols. It is clear that more than most Research Institutes and Universities, NMHSs these days aim more and more at institutionalization of the establishment of participatory services with farmers. The Mali agrometeorological pilot projects are among the best examples (see Part I and Stigter 2009). That is obviously because the word "Service" is in the name of these Institutions. But the development of "Services" Departments in Research Institutes and Universities would create a very important learning environment for those who want to bring science into the actual service to farmers (Stigter 2008b).

The third protocol, *Frost Forecast Service for Inner Mongolia in 2007 (China)*, is an example of the same kind. It belongs to agrometeorological services of the category H. but has components of E., while the defense measures we will discuss below belong to category D. However, expanding the definition of response farming as we recently did (Stigter 2008d), this may again as well be considered an example of category C (WMO 2010).

This is definitely an attempt at an institutionalized agrometeorological service, apparently applied on a larger scale in China, because the central China Meteorological Administration (CMA) asked the Provincial ones to collaborate in these developments. I was involved earlier in a frost forecasting publication in Iran (Rahimi et al. 2007). But that was a completely different approach. Not a period in which the frost could occur for the ongoing season but a general probability of occurrence was made available. The discussion here would again be whether farmers are really helped in the best way with such probability forecasts. Another advantage in the Chinese case is the concomitant advice on defense measures in case the crop cannot yet be harvested.

We wrote (Rahimi et al. 2007): “Bringing risk analysis of the last and first occurrences of frost and of frost-free periods to farmers in a way understood and appreciated by them is a very useful procedure to decrease frost hazards in farm management. It is believed that information on frost, provided along with information on the properties of climate, soil, and water, can help farmers to manage their agricultural activities much better. This can be considered an agrometeorological service to such farmers (e.g. Stigter 2005). A probability of occurrence of 75%, with a return period of 4 years, is a degree of risk that is accepted as an important yardstick when planning agricultural activities in Iran”.

What would be needed is of course in both cases a validation with independent data, to see how good the forecasts were and how they were used. Such validations are seldom built into the trials of such services. If built in, results are seldom made public. In both cases one would have to ask farmers for feedback. But in the Chinese case it is clearly indicated that the forecast is not given directly to farmers but reaches them through mass media as radio, TV, newspapers. In Iran the means of communication remained unclear. In both cases, using Climate Field Schools as such a meeting place of forecasters, or extension people trained by forecasters, and farmers would be a very good way of communicating the forecasts and obtaining feedbacks, also from more remote places.

The fourth protocol, *Design of Protection of Sloping Land from Soil Loss and Water Run Off Using Hedgerow Intercropping (Kenya)* gives the results of a project in which we had chosen for collaboration with an International Research Institute from the CGIAR. This was at the time the International Centre for Research in Agro Forestry (ICRAF). It is basically of the category D. (here with soil loss and water runoff as the disasters), again with the measures belonging to B., like in the first protocol above. One may also consider this work of the category J., with sloping land and water as the natural resources. It was “follow up” research of work we had done on alley cropping on flat lands (protocol number 9) at experimental fields outside the ICRAF fences. This was in the context of the National Dryland Agroforestry Research Programme (NDARP), because at that time (mid eighties) ICRAF was only a demonstration site, that was not allowed to do research on its premises! While they had done earlier work on sloping lands with a younger tree system and with the use of fertilizers. We both were therefore interested in what an aging tree system could do without the use of additional fertilizers on these sloping lands. A big advantage for us was that we knew that any results worth mentioning would go into the ICRAF extension system.

The most important farmers related issue in this work is the high efficiency of mulches in diminishing water run off. The hedges still also were very important in reducing soil loss, so they can’t be missed, their strong competition for resources not withstanding. What we learned was the importance of reducing the trade-offs between crop productivity and erosion control on sloping land in the semi-arid tropics. It appeared to be crucial to select hedgerows and to design hedge and tree spacings that minimize competition and provide adequate erosion control.

Although it was confirmed that it is difficult to increase LEISA crop yields in the semi-arid tropics with alley cropping on sloping land, it was also observed that strong remaining trade-offs need not be a major deterrent to adoption by farmers, in case grass and trees provide other direct and significant benefits to farmers. However, also the conclusions of Casey (2004) on adoption of agroforestry systems apply (see Box III.5.8 in Sect. III.5.2.(i)). It was concluded there that quite some agroforestry can be presented as a sustainable alternative to current methods of production in the tropics. If it is to succeed, the accompanying investments in the human capital of farmers through extension programs and on-farm training must be a part of the overall implementation strategy for agroforestry practitioners.

The fifth protocol, *Design of Multiple Shelterbelts to Protect Crops from Hot Dry Air (Nigeria)*, shows particularly the devastating practices of a government (in this case Forestry) Department to implement designs that were not based on thorough understanding of the micrometeorology involved and without involving local farmers. We must agree that it took us also quite some time before we understood that protection from hot dry air was what we observed in the quiet zone leeward of the belts. Only when the results of soil moisture data prior to sowing became available, we saw patterns explainable from decreased soil evaporation due to the protection of the soil from these same winds. The paper explaining this was refused by an agroforestry journal, because they did not believe us, but the same was accepted by a climatological journal. The category of services it belongs to is again D., with the disaster being the hot dry air blown by wind and the measures belonging again to category B., but one may also consider it an example of the G. category, the change being the desertification that occurred.

Another very important issue is the overwhelming influence on our understanding from the work done by a supportive M.Sc.-student on the socioeconomic aspects of the belts. The misconceptions due to this initial negligence were originally transferred to our team as well. Only after these socioeconomic surveys could we understand the situation in which the farmers were kept. It should be understood that the original designs were good enough to reclaim the area from desertification and to have protective grasses return. Only the crop protection from hot dry air was limited to about 5 and 6 times the height of the belts leewards and between 2 and 3 times windwards. Had they been perpendicular to the wind during the growing season, a distance of 10 times the belt height would have been sufficient for overall protection. But actual distances were between 15 and 25 times that height.

A final issue of importance here is the work done by another supportive M.Sc.-candidate on comparing traditional and scientific determination of planting dates. We have dealt with that issue in Box IV.4 of Chap. IV.4. We conclude there that, ideally, an agrometeorological advisory body should be formed by the government or NGOs that would be responsible, in a participatory approach with farmers and trained intermediaries, for predicting the onset dates "on line". That would be a highly needed institutionalization of this other service. This could guide decision making on (preparation of) sowing and on the safest types/varieties of crops to be selected. Again the Mali agrometeorological pilot projects are an example of this approach (Part I and Stigter 2009).

The sixth protocol, *Seasonal Vegetable Growing on Riverbeds – a Farmer innovation (India)*, is a straight example of category B. An approach where we originally aimed at also in our African research: to quantify traditional techniques of microclimate manipulation for a better understanding and for possible transfer to other places, eventually in a modified form. Our work on mulching, shading, wind protection and other surface modification as well as on drying, storage and related pests and diseases, as largely dealt with in Part I but also exemplified in Parts III and IV, was of that same kind. Eventual support to improvements would be of the category J.

The sowing places are low sand dunes that fall dry during certain parts of the seasonal flows. From the collected material it follows how conscious Indian farmers are of microclimate management and manipulation issues. Initially the young seedlings are watered with a hand-held watering can and later they take to the moisture levels themselves. The young plants are protected against frost and wind by erecting hedges of *Saccharum munja* at an angle of about 45° to the trench, across the direction of the wind. During summer, the earlier erected grass is spread on the sand and it protects the vines and fruits from direct contact with hot sand. This kind of traditional knowledge is confirmed by Box III.2.8 of Sect. III.2.1.(f), showing its importance for other groups of Indian farmers in the work of Murthy (2008). It is initially surprising that so few agrometeorologists have followed these traces, that we originally already started to draw in the eighties (Part I and Sect. III.2.1.(f)). But it is of course just due to a lack of research focus on the livelihood of farmers and their actual problems.

It is, however, good to know that this indigenous technique was already documented in an Indian Council of Agricultural Research (ICAR), New Delhi, publication "Validation of indigenous technical knowledge in agriculture", about a project on collection of documentation and validation of such knowledge. A study of raising cucurbitaceous crops in sand dunes under water scarcity condition was validated by the Division of Agricultural Extension of ICAR. It was concluded that this practice of vegetable growing during off season without irrigation was technically feasible and economically viable. This is a rare and precious example of validation of an innovative agrometeorological service developed by farmers for farmers. It is a precondition for further dissemination of this kind of practices, for example after calamities have stuck indigenous communities (Stigter et al. 2003).

The seventh protocol, *Agrometeorological Information for the Prevention of Forest and Wild Land Fires (Cuba)*, is an example of using (and comparing) institutionally empirical indexes in forecasting forest and plantation fires. The procedures described are carried out both in the meteorological stations and in the provincial office. Subsequently processed as an agrometeorological service, of the category E., supplemented with information from drought and weather forecasts (as services of the category F. and H.), it is transmitted from de Meteorological Center (automatically, and in some cases by phone) to the command post Forest Services in Villa Clara, agricultural enterprises, insurances sectors and government authorities.

In order to strengthen the surveillance system at the local level, the weather stations can provide this service to the units closest to the eventual request.

Validation and effectiveness of the service appear to be evaluated in partnership between forest authorities and the Meteorological Centre. This considers the number of fires detected during the season and agrometeorological conditions provided. No validation results were reported. It is great that validation is here part of the exercise from the beginning. Because it was noted that the characteristics of forest fires in Villa Clara did not differ significantly from the rest of the country, in addition to corroborating that the influence of extreme temperatures, relative humidity and accumulated rainfall at the beginning of the fires are crucial for their development, this makes the future spread to other provinces very feasible.

It is interesting to note that there is indeed ample scope for extension and generalization of the forecasting system to all comparable locations. The main constraint is availability and representativeness of meteorological data, again something we have come across rather often in agrometeorological services applications (Chaps. IV.6, IV.9 and IV.17). Consideration should again be given in a wider spread service to the validity of the indices used. As a difference with other countries, it is mentioned that in Cuba this service works at the local level, not at the national level. For a relatively small country, that is more surprising than in the case of say China. However, it very much depends on the value that national authorities give to a certain field of activities. With Cuba suffering from many disasters, where forecasting, preparedness and immediate decision making based on weather and climate are very important, such as with hurricanes, they are very well organized in these fields (Rivero Vega, Personal Communication 2008/2009).

The eighth protocol, *Furrow Planting and Ridge Covering with Plastic for Drought Relief in Semi-arid Regions (China)* is another simple microclimate management technique, as an agrometeorological service of the category B., reported from various places in China but also easily visible elsewhere in the world. Again this is also an example of land as well as water management with agrometeorological assistance (Category J.). Focused supportive research was reported here to exist for winter wheat and there is locally existing literature. One of the big difficulties encountered in China, on which we will come back later also in this Part II, is the low availability of reports on such issues in English. This has been my main reason to try, since 1997, to co-establish a program in China, on the collection and validation of such examples, on which we then should publish in Chinese and English.

Overall, there is of course no difference in precipitation received by the surfaces above ridges, furrows and level soils, but a rainfall reallocation is taking place between the plastic covered ridges and furrows. The water flows from the ridges to the furrows. And the result then is that much water is stored in the furrows, e.g. a 20 mm rainfall per unit of surface is equivalent to a 40–50 mm falling on the furrows. This enhances the plant available soil moisture.

This is a form of water harvesting on a small scale but over a large surface. In addition, soil evaporation is reduced by the film cover and this has another positive effect on moisture conditions, because more water remains available to the plants when the roots are able to reach it. The average daily mean soil temperature increased because of the film cover over the ridge, also in the furrow, at different depths. At 5 cm soil depth, for example, the temperature was raised in the order of 2° in the ridge and more than 0.5 a degree in the furrow, respectively. Before the wheat stops growth in the winter, soil temperature of the furrow at 10 and 15 cm was increased with less than a degree compared to level soil.

It is argued here, as in some other Chinese examples later on, that new focused research support can assist in the expanded and integrated use (that is further institutionalization) of these technologies in different regions according to the local natural conditions, such as climate, soil, topography and crop planting methods. From the view point of a rational utilization of natural water resources, weather and climate information should be available from the Provincial Meteorological Administrations and understood as a priority by the extension services concerned. This would mean that these extension services should also be trained in the establishment and validation of such agrometeorological services. The way this should reach the farmers in China will be discussed later in this part of the book.

The ninth protocol, *Design of On-Station Alley Cropping Trials on Flat Land in the Semi-arid Tropics (Kenya)*, is a report on very early on-station focused supportive research for the design of rain fed alley cropping agroforestry systems without the use of additional fertilizers on flat land in semi-arid areas. It is explained in this case study that alley cropping belongs to a large range of traditional and more recent attempts to make use of benefits of microclimate manipulation in tree intercropping. It is therefore basically of the category B. with again the possibility to consider it as a case of the J. category for land management.

The influence of trees on microclimate, particularly radiation and wind, so also soil and air temperature microclimate, heavily depends on heights and distribution patterns of the trees. In our alley cropping example dealt with here, the trees remained low, bush like, and their influence on radiation, wind and temperature in the rows where the crops were grown remained quite limited to the tree/crop interface and the earlier growth stages. In fact below surface soil conditions were influenced most by the presence of the alley trees. As soon as we work with hedges, shelterbelts and/or scattered trees of sufficient height to considerably influence the wind regime, also the other microclimatic factors are more seriously influenced. This includes rainfall redistribution after interception by the trees.

The quantitative assessment of the microclimatic effects of hedgerows and mulching in an alley cropping system was nevertheless important for evaluating the potentials of this cropping combination. It was even more important for semi-arid environments, where the experience is more limited. However, such attempts were rare and that made us decide to perform the agrometeorological service concerned. We have argued in Chap. IV.9 on the general importance of field quantification under such conditions. This study was particularly successful in developing new quantitative approaches for tropical conditions as to quantification of shade, soil temperature and soil moisture (Mungai et al. 1997, 2000).

It was shown in this work that yield increases due to tactical mulch incorporation were insufficient in the replacement agroforestry applied. Below a threshold rainfall, yields were even less than those in the controls (see also Box III.3.16 in Sect. III.3.4.(II)). It is argued also in this case study that the age of the agroforestry system also plays a role in these matters of competition, but influenced by the pruning regime applied to obtain the mulch for incorporation into the soil or distribution over the soil.

In alley cropping in semi-arid areas root pruning can not be exercised because this would limit even more the biomass production necessary for obtaining the mulch to be applied. In intercropping with hedges and scattered trees as well as with shelterbelts, where mulch use of loppings is not applied, tree root pruning successfully limits the competition of the trees with adjacent crops, particularly when the trees get older. However, tree growth is influenced by root pruning, depending on the pruning system applied and the rooting patterns of trees.

So, although the agrometeorological service came up with a largely negative advice, it was at the time an important service to be performed. In this case it was a validation of attempts that had been somewhat successful in the sub-humid tropics, but could definitely not been extended to flat land in the semi-arid tropics.

The tenth protocol, *Early Snow Melting Through Surface Spread of Soil Material (India)*, is again an example of attempts to study traditional techniques of microclimate improvement for a better understanding and for possible transfer to other places, eventually in a modified form. It is therefore of the B. category again, but may also be considered again as a form of agrometeorological assistance to land management (J.). This is an age old practice followed since the Epic Mahabharata in Lahaul and Spiti district of Himachal Pradesh. Farmers still utilize this practice of spreading the soil on snow for early melt of snow. This helps in early vacation of the fields for land preparation for the sowing of different crops.

Darker soil absorbs more heat than white snow and this heat is partly conducted downward, causing faster melting of the snow by about 8–30 days, depending upon amount of snowfall received during the season. This helps in early sowing of the crop(s) and enables the sowing of a second short duration crop like buckwheat, rapeseed or mustard. This case is a marvellous example of traditional “mulching”, changing the albedo (surface reflection) of the surface. It is of course very helpful to be able to take on a second short duration crop in snow bound areas.

It is again good to know that also this example is already documented in an ICAR publication “Validation of Indigenous Technical Knowledge in Agriculture” on collection of documentation and validation of indigenous technical knowledge. A comparative study for willow ash and fine textured soil with respect to their amount and efficacy was also already undertaken, as indicated in the protocol.

When I had started in Dar es Salaam to look around for examples of traditional knowledge and indigenous technologies that could be physically dealt with, we developed an outdoor demonstration experiment on the effect of soil albedo on soil surface temperature. This education related work was published by Stigter et al. (1984a). We also developed a physical theory on these phenomena (Stigter et al. 1984b). Finally, we used this approach to explain temperatures under mulched tea, by expressing the thermal efficiency of grass mulches as apparent soil albedos (Stigter et al. 1984c; Othieno et al. 1985).

These theoretical developments related to the interpretation of Kenyan mulch experiments for combating erosion in small farmer tea plantations, have played a large role in later modeling of mulch behaviour. The traditional mulching method for snow, changing the albedo, that was described in this protocol can be understood with such developments. Perhaps it would also help on frozen soils with light surface colors.

The eleventh protocol, *Water Use and Water Waste Under Traditional and Non-traditional Irrigation Practices (Sudan)* is another example of government requested scientific research in direct action support as agrometeorological service. It is of the J. category, but may also be considered an example of category G., because of the changes that had occurred in the modes of irrigation. In the Gezira irrigation scheme, serious symptoms of water waste had been identified from the mid 60s till the mid 80s, with modern irrigation approaches with less field attendance, especially in sorghum and groundnut fields. A serious debate among authorities on return to traditional irrigation methods or other possible solutions needed quantification of the wastes concerned. On their request a quantitative study was undertaken to this end that also should suggest ways to improve on the situation that are compatible with the local socio-economics of the use of sharecroppers.

Tenants were dissatisfied with overall maintenance of the scheme. Authorities (Ministry of Irrigation, Sudan Gezira Board) were dissatisfied with tenants' water use. These authorities were of the opinion that the farmers were wasting water by the unattended continuous (day and night) irrigation method they have evolved, especially for their private crops dura (sorghum) and groundnuts. There was the belief that remarkable savings in water would be obtained if the tenants would go back to the traditional night storage system, in which rather laborious and well-attended daytime application of water is practised.

To possibly strengthen but at least verify the arguments of those who want to change the situation, it was thought useful to accurately quantify the problems under participatory on-farm conditions. Quantitative agrometeorology has sufficiently strong methods to be able to do so. The study has revealed wastage of irrigation water in both, traditional and more recent irrigation methods, but at different rates and also differently for each crop. The waste was higher in unattended irrigation of both dura and groundnut, and the waste was larger on groundnuts. It had also larger consequences because groundnut yields drop with excess water applied. Even much of the consumptive use is economically ill invested in non fertilized dura, because with higher additional inputs the same amounts of water would give higher returns. The application differences were mainly due to the watering methods, causing different amounts of standing water, and the methods of determining the moment of irrigation. Another type of non-productive water is the readily available water retained in the soil profile at the end of each growing season.

More efficient water and farm management (e.g. weeding) in the scheme is crucial for obtaining somewhat higher yields with other external inputs remaining at the present low level. The most important measure in this respect would be to adopt a land levelling program to the practical limits possible and to apply partly or fully attended watering on small areas, as was recommended in the traditional night storage system. Minimum practical standing water in the furrows during and immediately after each irrigation must be targeted. The results strongly link the necessities of sharecropping and the unattended watering to socio-economic backgrounds. This weakens any assumption that the unattended watering practice is a mere water availability problem. Economic measures related to the payment and price of irrigation water should also be taken. The research was carried out in the Hydraulic Research Station (HRS) in Wad Medani, that directly reports to the authorities, of which many used to work there. Institutionalization therefore exists and validation is guaranteed.

The twelfth protocol, *Shelterbelt Design for Protection of Irrigation Canals and Agricultural Land from Blown Sand Encroachment (Sudan)*, is also again another example of government requested scientific research in direct action support as agrometeorological service. Like in the first protocol, the category of agrometeorological services to which it belongs is D., the disasters also here being desertification and wind blown sand. But, as many examples have shown already above, there are often double category services, because here the mode of the combating of the disaster as an agrometeorological service belongs again also to category B. A *Eucalyptus microtheca* shelterbelt, as an agroforestry technique which uses trees to protect land from moving sand encroachment, was planted by the Gezira Board and Forestry Authorities in an attempt to prevent such an invasion of sand. To understand the mechanism by which sand was settled within and in front of the shelterbelt, on their request a quantitative study was undertaken, that also needed to come up with design rules for shelterbelts to most efficiently combat such sand invasions. Such design rules must be considered an agrometeorological service to these authorities and to the farmers whose land got protected.

Contrary to its successor described in the first protocol, the agrometeorological service was immediately applied. Our results and existing literature on air movement around shelterbelts were used to indeed develop design rules for shelterbelts for sand encroachment protection. In these rules, composition and geometry of such belts were discussed as to length, width, height, permeability, direction, openings and species. Separate consideration was given to advice on trees to be used in such shelterbelt designs. Growth rate, life span and tolerance for drought, heat, pests and diseases, grazing, sand blast and sand deposition were mentioned. Canopy geometry and byproducts were considered with respect to air flow and economy.

It was proposed that dense shrubs in the front row(s), followed by tall strong trees, would do best from the windward wind reduction point of view. Some physical land treatments were suggested at the windward side of the belt, to trap some of the encroaching sand and hence increasing the life span of the belt. Some of these design recommendations, that were offered as agrometeorological service, were subsequently used in substantial belt extensions by the Authorities. These extensions for the time being successfully protect endangered parts of the Gezira Irrigation Scheme. This is at the same time a validation of the service developed. It is now proposed that the same design be used for the White Nile Sugar Scheme (west of the Gezira Scheme and east of the White Nile) that is under execution in the same affected area.

Irrigation canals could again be restored for carrying water and abandoned fields could again be taken into production, while other parts of the Gezira Scheme were protected from the beginning. The use of such shelterbelts nevertheless demands for concern about lasting sand deposition that can only be prevented if sand can be deposited/stored in the primary or secondary source areas. In a more recent development, the very poor local population living at the periphery of the belts developed *Acacia tortilis* plantings that, with controlled grazing, now protect, again for the time being, parts of the original belts. They succeed in settling the wind driven sand with these plantings in parts of the secondary source area near to the Sihaimab belts.

Sand settlement in the source areas is necessary for long term protection. Low and to a certain extent medium permeability, as well as the formation of clusters, enhance sand trapping at all sides of scattered trees and grasses, rather independent of wind direction. Scattered trees and grasses of the right kinds, densities and permeabilities have beneficial influence on wind by modifying flows in such a way that the flow capacities to carry saltating and creeping soil particles are sufficiently reduced. However, such re-vegetation has to occur over large areas. See also the first protocol. Institutionalization at the University of the Gezira of a planned TTMI-Unit has never taken place due to lack of international funding. Without such funding and lasting international collaboration, this type of research cannot be carried out at Sudanese Universities or Institutes.

The thirteenth protocol, *Design of Improved Underground Storage Pits (Matmura) for Sorghum in Cracking Clays (Sudan)*, is an example in which good farmer surveys among very poor farmers contributed from the beginning to a better approach of the problems, taking the results of farmers' experiments into account. Extension problems were then recognized. For the category B., the advices are now on design rules on mainly below ground microclimate manipulation. Predictions of climate changes (category F.) were at the basis of these developments that therefore also may be seen as belonging to category G., with the measures remaining of the B. category.

The Jebelmuoya area in Sennar State is officially defined as rain fed, undemarcated land and has lower rainfall and poorer soils than the large mechanized farming schemes established in nearby demarcated areas. Smallholdings in Jebelmuoya vary considerably in size and are supervised by the Small Farmers' Union for Un-demarcated Areas. Unlike farmers 30 km away in the Sennar Agricultural Extension Unit, who also use the matmura system, smallholders in Jebelmuoya are not considered part of the modern sector and are, therefore, not eligible for government services. Their poverty has made the smallholder communities of Jebelmuoya particularly vulnerable to the climatic changes affecting the region as a whole. They stagger their sorghum planting in time to offset the risks of crop failure and need storage facilities that will preserve sorghum long enough to carry them through periods of crop failure and food shortage. However, at the moment there is little to encourage them to invest their meager resources in improving their matmuras. Information is scarce and practical help and advice largely unavailable.

There is an urgent need to disseminate these types of research results. The government extension services have an important role to play in this process but at the moment indigenous farmers are largely excluded from extension networks. Even though there is an extension station in the nearby town of Sennar, officials there have no communication links with farmers in Jebelmuoya.

This is again a case showing the necessity of differentiation of farmers, with government and NGOs jointly being responsible for listening to needs, getting them recognized and addressed in a participatory approach in the livelihood of these various groups of farmers. We have contributed not only by studying the storage systems but also by forcing authorities to recognize that the political decision making environment played against these target groups. Only political moves can change this situation before the knowledge obtained can be of any use to much larger groups of these farmers.

The fourteenth protocol, *Improved Design of Millet Based Intercropping Systems Using On-Station Field Research and Microclimate Manipulation (Nigeria)*, has again been left at the "focused scientific support" status. The main reason here was that the University had lost contacts with the target groups of farmers concerned, so we had their cropping and farming systems reviewed independently. The hypothesis was tested, for the most abundantly occurring intercrops in semi-arid northern Nigeria identified this way, that these systems are generally more efficient in resource use under drier conditions than sole crops. This was done for dryland intercropping, with heterogeneous mixtures derived from patterns and varieties that farmers preferred, at low densities on-station. A quantitative project was set up on resource use, with soil water balances, dry matter production and yield determinations, leading also to numerical crop productivity/water use relationships.

The agrometeorological service delivered, which is mainly again of the B. category, as most examples of the TTMI-Project (Part I and e.g. Chap. IV.9), here as a design of desirable above ground microclimates in intercropping, could also be seen as agrometeorological assistance to management of crop structural and growth resources in intercropping (category J.). The particularly intensive study of root systems also points in this direction (WMO 2010).

The most dominant crop mixtures are millet/cowpea, millet/sorghum/cowpea, millet/cowpea/groundnut, sorghum/cowpea and sorghum/cowpea/groundnut. Cowpea has a dual purpose: the grain is used for human consumption and the remaining biomass as fodder for animals. Some cowpea varieties are planted specially within the intercrops for fodder production, producing little or no grain, to take care of animal feeds during the dry season The cowpea component of the mixtures also often consists of two types, i.e. fodder and grain types that differ in growth habit and maturation period. The cereals are grown for consumption and cash. Intercropping components adopted by farmers are grown at low densities, to minimise risks and exploit resources in a good cropping season well.

All the crops sown sole and intercropped 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. 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 sole, 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. This is immediately useful knowledge as an agrometeorological service for designing such systems.

The density and morphological characteristics of crops in association influence the microclimate within the various cropping systems. The reduction of soil radiative and heat exchanges (reduced surface soil temperature fluctuation), by a well developed low growing cowpea component in an intercropping system, is capable of reducing soil evaporation better than in the sole cereal systems and hence offers a better soil water conservation practice in the arid and semi-arid zone of Nigeria. An answer with a view of improving the cereal/legume systems in the Nigerian arid and semi-arid zones should therefore include genetically superior crop cultivars and the manipulation of the component densities along with the improvement of microclimatic variables.

The results learn that abundant organic manure in combination with agrometeorological services on intercrop manipulation related microclimate improvements may control near surface land degradation in northern Nigeria under acceptable sustainable yields. Appropriate policy environments, in economics and research, must enhance this.

The fifteenth protocol, *Design of Wind Protection Agroforestry from Experience in a Demonstration Plot of Hedged Agroforestry (Kenya)*, is reporting on demonstration plots that had been decided on in consultation with the Swiss Laikipia Research Project (LRP) in Nanyuki and local provincial authorities. A traditional maize/bean intercrop was grown in a wind protective agroforestry system with all around hedges and trees in this semi-arid region. A quantitative project was set up to determine the feasibility of this set up for the farmers that recently immigrated to this area from the Central Province of Kenya, as to yields and their sustainability compared to non-agroforestry control plots. The example was again of the B. category but because of the changes in the livelihood of those farmers, it may also be considered to be of the G. category with B. delivering the means.

Unadapted intercropping systems, introduced by immigrants, are causing low yields and land degradation. Water runoff, increasing climate variability and dietary habits of the population are also involved. In Laikipia district, deforestation, overgrazing and strong winds worsen the situation. An ideal protective mixed cropping system for these farmers would be an agroforestry system in which tree roots and crop roots colonize different soil layers and system components render services mutually. Because of initially high risks, on-station demonstration plots were chosen for introduction of such systems.

It may again be concluded that some configurations of trees, with the right distributions of biomass, can modify airflow positively and in this case sufficiently reduce mechanical damages of the protected crops and prevent the blowing off of mulches. However, strong biomass gradients, such as in gaps, as well as generation of additional turbulence should always be prevented, like this is also the case in the design of shelterbelts. The results were transferred through the local contacts that the

Laikipia Programme had developed and through direct contacts with those farmers that could be shown the results of the demonstration projects. The next step should have been further validation of improvements and alternatives on their own farms.

Farmers could be shown that combining the root pruned hedge protected system with root pruned *Grevillea robusta* trees made it economically more attractive and made it aerodynamically more efficient to diminish mechanical damage to the intercrops and improve soil water availability to these crops. The results learn that under the very difficult semi-arid conditions in Laikipia, the mulched tree cum hedge pruned agroforestry system overall helped to limit land degradation. However, the farming conditions are extremely marginal and economically more viable systems must be developed as (agrometeorological) services, to help the migrated farmers concerned.

The sixteenth protocol, *Applying Straw Mulch on Winter Wheat in Winter to Improve Soil Moisture Conditions (China)*, is another example of simple microclimate management and manipulation with the practice of mulching. So, for categorization, it definitely belongs to the B.-type. Because it is also water management that is carried out here with agrometeorological assistance, also the J.-category should be mentioned in the typology of agrometeorological services. It is again one of the management possibilities one sees applied across Asia and Africa on which much is known and much has been written, but in the developing world mostly in the gray literature. Indeed, with little exception science and third world practices are separately dealt with. The exceptions are found in Parts I and III of this book.

By comparison with uncovered winter wheat, it was shown that the soil water content of winter wheat mulched with corn straw was much better, especially before the wheat elongation stage in spring. The microclimate of wheat fields was changed evidently under straw mulching. According to field measurements, air temperature and turbulence near the surface increased, and air humidity and sub-soil temperature decreased in mulched wheat fields. Looking at the energy balance, mulching caused an increase of sensible heat flux (from a warmer surface) and a decrease of latent heat flux, so the soil evaporation from mulched wheat fields was reduced and the transpiration of wheat was increased after the elongation stage.

The total evapotranspiration over time may not have increased. It may have only changed the water consumption in time and way. In winter (mulched period), soil evaporation decreased and soil water increased; after the elongation stage, wheat transpiration increased. The water for larger soil evaporation was converted to wheat transpiration through mulching wheat in winter times.

This example will come back, as the only one, in the ten Chinese examples from another project dealt with in this Part II of the book.

The seventeenth protocol, *Using Shade Trees to Ameliorate the Microclimate, Yields and Quality of Tea (India)*, is another well known example of microclimate management and manipulation on which much has been written. The environment concerned here is harsh. Advection of hot air, high rainfall and hail storms as well as high solar radiation loads occur during the summer. Soil erosion, low water holding capacity and low fertility of silty clay loam soils are other negative conditions. The growing of shade trees is an age old technique, practised in the tea gardens in Himachal Pradesh. Shading by trees provides a number of known benefits to tea plantations including microclimatic improvement and resultantly higher growth rates and better quality of tea leaves as well as better economic returns. The category of this example is therefore again B., but it may be argued also that additionally this is an example of category I., the shade trees being additional absorbers of carbondioxide. Such an argument for cocoa was recently well received (Stigter and Abdoellah 2008) as we will explain in Sect. III.3.5.(α).

Umbrella type shade trees covering the tea gardens indeed protect them from direct sunlight, scorching heat and warm air currents. High temperatures in unshaded tea in the peak growing season drastically reduce tea yields because tea leaf temperatures exceed critical values and photosynthesis slows down. The compatible shade tree species filter solar radiation by cutting off near infrared solar flux and transmit sufficient light intensity for optimum photosynthesis. This results in lower ambient, leaf and soil temperatures and the retaining of soil moisture. It increases leaf area, number of pluckable shoots, so yields. It improves tea quality to some extent by promoting the content of caffeine, polyphenols and other taste determinants.

Generally, in the order of a 100 trees are maintained over 1 ha area. A higher density of shade tree species takes away too much of the direct sunlight, which promotes the attack of Blister Blight, which is a major tea fungal disease. With maintaining an optimum density of shade trees, also competition for water and nutrients is kept within limits. A well planned experiment could with focused scientific support test the optimum planting densities of shade tree species and quantify the benevolent effects of this system, at the same time validating the present practices.

The radiation is reduced by the order of 35–40% of total incoming solar radiation. The shading trees generally belong to leguminosae families, having the capacity of fixing atmospheric nitrogen and generating a good amount of foliage, shedding of the same at the time when the organic matter is greatly needed for building up the fertility levels and providing the requisite sunlight at the critical stage to the tea plantation. The by-products of shade trees provide fuel wood and hence save energy in the tea processing industry. It is this way a well established farming system with a built-in agrometeorological service long practised from ancient experience and innovations.

The eighteenth protocol, *Explaining Wind Protection of Coffee from Umbrella Shade Trees (Tanzania)* is very comparable to the previous example, with the difference that the shade trees on the slopes of the Kilimanjaro were particularly kept by the farmers for wind protection. But we would be inclined to categorize it as an example of D., with the wind gusts in front of showers being the natural disaster, that is combated via means under category B. and may be seen as belonging to I. as well, because of the additional carbondioxide absorption by these trees (see Sect. III.3.5.(α)).

It was indicated to us that the extension services wanted to cut the shade trees as no longer recommended. However, the farmers refused because of their experience with the wind protection provided by these trees to the coffee, particularly during high winds preceding showers. As to the quantification aspects, we had to use indirect proof here because equipment to measure vertical air movement we did not have. However, we also had observational evidence that unprotected coffee suffered damage from wind gusts while protected coffee in the same fields did not. Wind speeds measured with anemometers that quantified gusty winds with large angles of attack from the horizontal indicated the protective qualities of the shade trees and the absence of much wind tunneling. It was proven that, in comparison with unprotected coffee trees, the umbrella type shade trees indeed protected the coffee from mechanical damage of vertical air movements preceding showers. It was an agrometeorological service to recommend through the Lyamungu Coffee Research Institute to the extension service and farmers that the shade trees should be kept for wind protection.

An essential feature here was again that such problems and such an antagonism between extension people and farmers have to be brought to scientists' attention. Because of the open mind of the Director of the Coffee Research Institute, understanding what kind of research we were after when we took the initiative to visit him, he put this issue on our plate. It is one of the best roles that science can play, to be able to make such problems understood and solve the antagonism by scientific experiments and reasoning. Much indigenous knowledge can this way be tested (see also Chaps. IV.4 and IV.9) and its value be assessed for present day farming conditions in comparison to alternatives that can also be scientifically approached.

The nineteenth protocol, *Development and Establishment of a Drought Early Warning System (Cuba)*, was specially designed to be useful to governmental planners and decision makers at the local, municipal and provincial levels. But it is also used in direct services to farmers, farmers associations and governmental insurance companies. It should be categorized as E., having to be followed by drought combating measures to which it should be connected in agricultural undertakings. Expanding the definition of response farming as we recently did (Stigter 2008d), this may as well be considered an example of category C. (WMO 2010).

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 emergence". This drought became known as the "Camaguey cattle emergence" and established the relevance of "SAT", of which improved versions are now available. 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 (WMO 2010).

Services are being extended to include not only meteorological and agricultural drought but an early warning system for hydrological drought (ongoing research project). A new Web-based SATIV version is being made (ongoing research project) and a national version (ongoing research project) including pest and disease forecasts is also under construction. These three projects were approved and funded simultaneously in 2004–2005. They are all in execution now. Systems such as this should be tailored according to local technological, geographical and institutional conditions (including political organization). The system could also be improved using radar measured precipitation amounts, satellite measurements and improved water balance models. But it is clear that the use of remote sensing would be very costly for operational systems that work at daily time steps. In this sense you could say that funds are simply limiting.

A complete economic assessment has not been made because (1) social impacts and political impacts are so obvious that nobody questions the role of the system; and (2) the operation of the system is practically inexpensive and needs only a disciplined operational meteorological network and a bunch of dedicated people. Several high-level authorities have described the situation in the same terms, at different and independent occasions: "The most important achievement of the Early Warning System for Agricultural Drought in Camagüey has been the creation of a new culture on drought problems and how to deal with them. This culture doesn't exist anywhere else in Cuba and should be extended as far as possible".

The twentieth protocol, *Development of a Web Based Optimal Irrigation Calendar (Portugal)*, is another representative example of an institutionalized as well as validated agrometeorological service related to irrigation, a measure belonging to category D. With also here the annotation that it also belongs to type J., with water being again the natural resource concerned.

To combat drought and to assist water use efficiency, since 1999 an Operational and Technological Irrigation Centre (COTR) in Portugal takes advantage of ICT 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, the region most common soils, crops and technologies, and users data.

The farmers' irrigation needs can be obtained on line, in real time, if the user inputs his/her own water supplies. Multiple output stations are in use: internet with a web interface; internet with a personal digital assistant; mobile phone with SMS messages. Consequences of climate change will be shown by the records over time and may also be predicted (WMO 2010). The information system is supported by a relational database where the weather station and user data are stored and where information characterizing the region's most common soils, crops and technologies is also kept. This last information is also resulting from other R&D projects undertaken by COTR.

After the service implementation, farmers believe that they can improve irrigation scheduling of their crops. Every year the number of users is increasing. The biggest difficulties are related to the low use of web services by Portuguese farmers (only less than 20% frequently uses the web). Nowadays the service is based on periods of a week. Initially farmers are not receptive to such matters, but after some information or after the first year they are asking for daily information. The main objective of the service is to reach all regions of Portugal where irrigation is an important agricultural activity.

This kind of services are essential for a good irrigation scheduling, but we can't expect that farmers will use it often by themselves. It is very important to develop an irrigation extension service with technicians prepared to assist farmers, using the required tools. These technicians are connected to COTR, that will help them any time anywhere. These technicians are the extension intermediaries that can teach the farmers after they have been thoroughly trained themselves. This is the ideal built up for establishment and application of agrometeorological services.

References

Casey JF (2004) Agroforestry adoption in Mexico: using Keynes to better understand farmer decision-making. J Post Keynes Econ 26:505–521

Chambers R, Pacey A, Thrupp LA (eds) (1989) Farmer first: farmer innovation and agricultural research. Intermediate Technology Publications, London, 219pp

INSAM (2005) Results of the 2005 INSAM contest on the best examples of agrometeorological services. Available at www.agrometeorology.org under the topic "Accounts of Operational Agrometeorology" of December 6

INSAM (2007) Results of the 2006 INSAM contest on the best examples of agrometeorological services. Available at www.agrometeorology.org under the topic "Accounts of Operational Agrometeorology" of February 19

INSAM (2008) Results of the 2007 INSAM contest on the best examples of agrometeorological services. Available at www.agrometeorology.org under the topic "Accounts of Operational Agrometeorology" of April 17

KNMI (for Netherlands Government, compiled by Kees Stigter, second update) (2009) Capacity building in the area of agrometeorological services through roving seminars. Document originally distributed and presented as CAgM-XIV/INF. 4 at the XIVth Session of the WMO CAgM, New Delhi, October/November 2006, 13pp

Mungai DN, Stigter CJ, Coulson CL, Ng'etich WK, Muniafu MM, Kainkwa RMR (1997) Measuring solar radiation transmission in tropical agriculture using tube solarimeters. A warning. Agric For Meteorol 86:235–243

Mungai DN, Stigter CJ, Coulson CL, Ng'ang'a JK (2000) Simply obtained global radiation, soil temperature and soil moisture in an alley cropping system in semi-arid Kenya. Theor Appl Climatol 65:63–78

Murthy VRK (2008) Report on the project entitled "WMO-ANGRAU-DST sponsored Roving Seminars on Weather, Climate and Farmers". Available on the INSAM website www.agrometeorology.org under "Needs for agrometeorological solutions to farmer problems"

Nicholson C (2009) Bringing the internet to remote African villages. The New York Times of 2 February. http://www.nytimes.com/2009/02/02/technology/internet/02kenya.html

Othieno CO, Stigter CJ, Mwampaja AR (1985) On the use of Stigter's ratio in expressing thermal efficiency of grass mulches. Exp Agric 21:169–174

Rahimi M, Khalili A, Hajjam S, Kamali GA, Stigter CJ (2007) Risk analysis of first and last frost occurrences in central Alborz region, Iran. Int J Climatol 27:349–356

Stigter KCJ (2005) Building stones of agrometeorological services: adaptation strategies based on farmer innovations, functionally selected contemporary science and understanding of prevailing policy environments. Opening key note lecture at the FPEC Symposium, Fukuoka, Japan. J Agric Meteorol (Japan) 60:525–528

Stigter CJ (2008a) Agrometeorology from science to extension: assessment of needs and provision of services. Invited lecture at the 50th anniversary of the Chinese Academy of Agricultural Sciences, Beijing. Agric Ecosyst Environ 126: 153–157

Stigter K (2008b) Getting agrometeorology to reach all farmers. Report of a mission at the University of the Free State, Bloemfontein: 12/1-30/4/'08. Agromet Vision, Bruchem and Bondowoso, 76pp

Stigter CJ (2008c) Operational agrometeorology: problems and perspectives. In: Souvenir, International Symposium on Agrometeorology and Food Security. CRIDA, Hyderabad, pp 41–47

Stigter K (2008d) Agrometeorological services under a changing climate: old wine in new bags. WMO Bull 57(2):114–117

Stigter CJ (2009) Scientific support to the establishment and validation of agrometeorological services. SciTopics. Research summaries by experts. Elsevier, Amsterdam.
http://www.scitopics.com/Scientific_support_to_the_establishment_and_validation_of_agrometeorological_services.html

Stigter K, Abdoellah S (2008) Cocoa and climate change, can the lame help the blind? Invited Paper Presented at the "2008 Indonesian Cocoa Symposium", Organized by ICCRI, Jember, at Sanur, Bali. An updated version is available at the INSAM website www.agrometeorology.org under "Needs for agrometeorological solutions to farming problems" of 3 November

Stigter CJ, Mjungu YB, Waryoba JM (1984a) An outdoor demonstration experiment on the effect of soil albedo on soil surface temperature. Am J Phys 52:742–744

Stigter CJ, Mjungu YB, Lutege PMB, Waryoba JM, Othieno CO, Mwampaja AR (1984b) Relationships between soil albedos and soil and air temperatures. Neth J Agric Sci 32:33–42

Stigter CJ, Othieno CO, Mwampaja, AR (1984c) An interpretation of temperature patterns under mulched tea at Kericho, Kenya. Agric Meteorol 31:231–239

Stigter CJ, Das HP, Murthy VRK (2003) Beyond climate forecasting of flood disasters. Invited Lecture on the Opening Day of the Fifth Regional Training Course on Flood Risk Management (FRM-5). Asian Disaster Preparedness Center (Bangkok) and China Research Center on Flood and Drought Disaster Reduction (Beijing), Beijing, September. Available from ADPC (Bangkok) on CD-ROM. Also available at http://www.agrometeorology.org/fileadmin/insam/repository/ADPC2mp.pdf

Winarto YT (2007) "Bull" versus "Tiger": can the "Bull" and the "Tiger" work collaboratively? A reflection of "Farmer First" in Indonesia. Presented in "Farmer First Revisited: A Workshop on farmer innovation and agricultural research and development twenty years on". Institute of Development Studies, University of Sussex, Brighton, December. http://www.future-agricultures.org/farmerfirst/files/T2b_Winarto.pdf

WMO (2010) Agrometeorological services: reaching all farmers with operational information products in new educational commitments. Brochure prepared by Stigter CJ. WMO, Geneva, in press