Applied Agrometeorology of Today: Some Case Studies and New Trends

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Abstract

One of the most important trends in agrometeorology is the development of agrometeorological services with and for farmers. The issue is that they must be explained to and discussed with these farmers and then must be applied in cultivation planning/actions and finally also evaluated with them. The second trend therefore is a "farmers first" paradigm in a participatory approach. An important class of services is the design of new cropping/farming systems that can face new requirements of the "farmers first" paradigm. Three examples of intercropping farming systems have been selected and climate change and cultivation aspects of these designs will be dealt with. Dryland intercropping with heterogeneous mixtures in semi-arid Nigeria is the first example. Demonstration and extension of relay intercropping of late rice into lotus in Guangchang County, Jiangxi Province, China is the second. Land scarcity forcing farmers in semi-arid Kenya to cultivate more sloping land is the third. The next trend to be discussed is generating and supporting a rural response to climate change in agrometeorology. We use case studies from Indonesia. Collection and generation of on-farm knowledge will very much help. If we succeed in creating such weather services, consequences of climate change can be faced with much more confidence. In Indonesia experiments have taken place with local Climate Field Schools (CFSs) as a new trend in agrometeorology. We finally have experimented there with so called "Science Field Shops", which should become a new trend. The applied agrometeorology of today is what scientifically supports those trends.

INTRODUCTION

One of the most important trends in agrometeorology is the development of agrometeorological services with and for farmers (Stigter, 2010). We consider that to agrometeorological services belong all agrometeorological and agroclimatological knowledge and information that can be directly applied to try to improve and/or protect the livelihood of farmers. This means protection of yield quantity and quality and farmers' income, while safeguarding the agricultural resource base from degradation (e.g. Stigter, 2010; WMO, 2011).

An obvious example is of course a specific weather forecast for agriculture, but the issue with actual agrometeorological services is that such a forecast must be explained to and discussed with these farmers and then must be applied in cultivation planning/actions with them and finally also must be evaluated with them (Murthy, 2008). The same applies to other agrometeorological services such as simple seasonal climate predictions, early warning messages and other disaster preparedness attempts (Stigter, 2010). Such an approach fits the "farmers first" paradigm excellently. The second trend therefore is a "farmers first" paradigm in a participatory approach (e.g. Stigter, 2011a).

Another class of such services is the design of new cropping/farming systems that can face new requirements of the "farmers first" paradigm. The organizers asked me to exemplify cases of multiple cropping systems. Three examples of intercropping farming systems will be dealt with below and climate change and cultivation aspects of these designs will be dealt with (Stigter, 2010). The next trend discussed is that of generating and supporting a rural response to climate change in (among others) agrometeorology (Winarto and Stigter, 2011). We discuss it for agrometeorology using case studies from Indonesia. An example of the latter is the research we do in Yogyakarta and west Java, Indonesia, stimulating farmers since 2007 to measure rainfall patterns in their own fields and to follow the consequences for their crops and fields, growing season by growing season (Winarto et al., 2008; Winarto et al., 2010). These on-farm data and information are then discussed among themselves and with supporting scientists. If we succeed in creating such weather services, consequences of climate change can be faced with much more confidence. In Indonesia experiments have taken place with local Climate Field Schools (CFSs) as a new trend in agrometeorology. However, the top down approach with the curricula, "teaching" farmers agrometeorology, left much to be desired. We therefore advocate bottom up agrometeorological learning processes, focused on weather and climate vulnerabilities of the farming systems concerned (Winarto and Stigter, 2011). To that end we have experimented in Indonesia with so called "Science Field Shops", which should become a new trend. The applied agrometeorology of today is what scientifically supports those trends (Stigter, 2010).

INTERCROPPING EXAMPLE FROM SEMI-ARID NIGERIA

The major cereals adapted to the rainfed region of the Nigerian Sudan savannah are pearl millet (*Pennisetum glaucum* (L.) R.Br) and sorghum (*Sorghum bicolor* (L.) Moench). These cereals are predominantly intercropped with cowpea (*Vigna unguiculata* (L.) Walp) and/or groundnut (*Arachis hypogaea* (L.)). 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 feed 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 maturity period (Stigter et al., 2005).The cereals are grown for consumption and cash (Beets, 1990). Intercropping components adopted by farmers are grown at low densities, to minimize risks and exploit resources in a good cropping season. They are grown on soils too low in water holding capacity for the precipitation - falling in heavy showers - to meet evaporative demands of the atmosphere (Oluwasemire et al., 2002). High year-to-year variability of rainfall (Ati et al., 2009), serious deep percolation (Oluwasemire et al., 2002) and high wet soil evaporation losses (Kinama et al., 2005) are additional stresses. There is need for better understanding of the traditional intercropping systems. This would improve the possibility of mitigating the limiting factors, as well as making optimum use of the limited resources (Stigter et al., 2005), while it serves also to face the changing climate conditions (Stigter, 2010).

Because of intensification of land use over the years, there have already been long lasting changes in surface microclimate. The efficient use of the limited effective rainfall in this zone is therefore a crucial factor for future increases in crop production, which should come primarily from increased yield per unit area of land (Jagtap and Chan, 2000). Low harvest indexes (HI) may result from the reduction in the supply of assimilates, when competition for water in the root zone occurs during the yield production stage (Fukai and Trenbath, 1993).

Sorghum root production was greater than for millet, while both cereals produced greater root density than cowpea. 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 conditions. 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 useful knowledge for designing such systems.

Millet was the dominant crop in dry matter production in the intercrops. This was due to the faster growth and high tillering rates of millet, especially when sown at low density. The soil fertility treatments did not create any statistical significant differences in yield and yield components of millet at harvest in all the cropping systems. To fight land degradation, a consistent incorporation of organic manure at seasonal level is a way of improving soil physical and chemical conditions aimed at conserving soil water. The improvement of the soil nutrient status by an increased application of organic manure may also encourage the manipulation of the intercrop components, such that an increase in plant densities would make better use of soil water that would otherwise have been lost to soil evaporation and deep percolation beyond the rooting zones (Stigter et al., 2005). Such designs nicely fit a "farmers first" paradigm.

The farmers' practice of planting millet and/or sorghum earlier in the intercropping systems relative to the cowpea components affords the cereal components, especially millet, with a relatively faster rate of assimilate accumulation, more competitiveness for resources than the other crops in association. The implication of this practice are the negative effects on cowpea yields as shown in our case. 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. An amelioration of the cereal/legume intercropping 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 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 (Stigter et al., 2005). When these issues are attended to, consequences of climate change can be confidently faced as well in a "farmers first" paradigm.

INTERCROPPING EXAMPLE FROM GUANGCHANG, JIANGXI PROVINCE, CHINA

Stigter (2010) recently argued that the issues to attend to appear to be (i) what multiple cropping systems have as defence strategies to extreme meteorological events that are less efficient or not available in monocropping and (ii) what science can contribute to understanding and developing such strategies. Where knowledge is operational at all in agrometeorological services, it is mainly for monocropping, perhaps for sequential cropping, but it remains marginal for mixed (inter)cropping and relay (inter)cropping, with the exception of the long recognized but insufficient exploited protection functions of trees in agroforestry applications (e.g. Stigter, 2011c).

In the area concerned, a double rice crop (early rice and late rice) used to be grown everywhere and is still abundantly grown. Because of the slow global warming, the seasons become longer. Now into lotus, that is sown by the end of March, early April, and gradually harvested between July and September, late rice is transplanted as a relay crop, roughly between 10 and 20 August. Because of the lotus, the rice is 45 days in the nursery, 10 days longer than normal, so the rice is transplanted later than usual. But the land is now occupied after the lotus, that is harvested till September, while the later sown early maturing rice variety occupies the land till into November.

In Stigter's (2008; 2011b) categorization of agrometeorological services, this example should mainly be seen as from the category "Development and validation of adaptation strategies to changes". However, it has also elements of "Advices such as in design rules on above and below ground microclimate management and manipulation", where it shows "fitting the crop to the season" aspects of microclimate management, as in Stigter's earlier categorization of microclimate related work in agriculture in the early eighties (e.g. Stigter, 1994). This also comes back in the choice of earlier maturing varieties of late rice, and in microclimate issues of the lotus crop, such as in positive shading, that should be further researched.

The lotus normally fetches a high prize and the rice is an additional bonus. The lotus may lose 10% of its harvest because of the rice but under land scarcity the late rice is a useful addition. In the seventies this would not have been possible, but climate change makes it possible. Of course under early cold waves the rice will lose in production. During the demonstration, Meteorological Bureaus signed contracts with farmers, according to which the former subsidized seeds and fertilizers. They would also compensate any losses compared with growing sole white lotus or a double rice crop in case of failure of the interplanting.

For extension, here eight times a kind of Climate Field Classes was organized to demonstrate and popularize the method with the target groups concerned and a class room was available for training.. As we earlier indicated, a comparison of such an approach (e.g. Winarto et al., 2008) with the "cascade" down coming of extension information in China would be a great last phase of the pilot projects started there in 2004 (Stigter, 2009a; 2009b).

Another important lesson learned here is the economically successful adaptation that is provided to a changing climate. Only some decades ago, the present development would not have been feasible in this farming system. This is a warning against any trend of scenarios projecting present cropping systems into the future and then detailing their suffering from climate change (Stigter et al., 2008). There are many ways for adaptation through agrometeorological services and farmers are keen to innovate and follow up (e.g. also Winarto et al., 2008). By sticking to a "farmers first" paradigm, such errors would not be made.

LAND SCARCITY IN KENYA FORCING FARMERS TO CULTIVATE SLOPING LAND

One way to fight land degradation without using expensive inputs could be the use of agroforestry systems, particularly alley cropping (hedgerow agroforestry). Mungai et al. (2001) showed that for flat land, without fertilizers, yield increases from mulch incorporation in semi-arid Kenya were insufficient when maize rows were replaced by trees. Below a threshold rainfall, yields were even less than those in the controls (Mungai et al., 2001). As below ground resources become more depleted with colonizing ageing systems, tree growth occurs even more at the expense of crop production (Kinama et al., 2007).

Contour hedgerows on sloping land should be able to capture the runoff and soil, which would otherwise be lost from hillside cultivation, and thereby compensate at least in the long run for the extra resources required for tree growth (Stigter et al., 2005). Contour plantings of trees on hill slopes are highly effective in reducing water caused soil erosion and have provided more encouraging results than alley cropping on flat lands. Tillage and mulching reduce rain impacts on cropped soil and provide roughness that slows losses of soil and water. Infiltration beneath the hedgerows was greatly improved, due partly to the physical barrier effect of the stems and partly by an increase in macropores under the hedgerows. More water appeared to be stored and to a greater depth under the hedges than elsewhere (Kiepe, 1995).

However, high water losses from soil evaporation have been reported (Kinama et al., 2005), while Mungai et al. (2001) proved patterns and densities of overlapping roots between maize and *Senna siamea* to be involved in lower yields in middle rows. For such reasons beneficial effects on crop yield are seen as often unpredictable and insufficient to attract widespread adoption. Initial enthusiasm for contour hedgerows was dampened by their slow and sporadic adoption, even in humid and sub-humid regions. Few farmers can afford to invest in any soil conservation measures which do not improve their crop yields, let alone sacrifice crop yields in drought seasons (Garrity et al., 1999).

"On-station" comparison was made of erosion control from contour *Senna siamea* hedgerows and *Panicum maximum* grass stripson a 14% Alfisol, intercropped in rotation with maize and cowpea, without the use of fertilizers and with hedge/strip spacings of 4m. Kinama et al. (2007) quantified multi-season trends in runoff, soil loss and productivity of the *S. siamea* contour hedgerow systems first successfully used by Kiepe (1995) from 1989-1992 with the use of fertilizers. They examined the trade-offs between soil conservation and crop productivity without fertilizers for these now mature systems, from 1993-1995.

Cumulative runoff was reduced from close to 100 mm to only 20 mm. Cumulative soil loss reduced from more than 100 ton/ha to only 2 ton/ha. But this was at the expense of 35% of the maize yields and 25% of the cowpea yields due to competition. The presence of surface mulch was clearly the most important factor in reducing runoff since their removal resulted in an additional cumulative loss of 56 mm. On the other hand, the presence of the hedgerows was much less important in reducing runoff, e.g. only an extra 23 mm was saved by this treatment as compared to the controls (Kinama et al., 2007). This is not in line with the results with the younger system, where hedges were still more important than mulches in the runoff control, but for the hedges the lower soil loss compared to mulches remained in line with the younger system (Kiepe, 1995).

The grass strip results for runoff and soil loss reduction were halfway between the values for the hedges with and without mulches. But the yield reductions were highest for the grass strips. The grass strips were more effective in preventing soil erosion than the hedgerows (without mulch) because of the compactness and thickness of the grass strips. The latter are more effective in reducing runoff speed and trapping soil than the thinner and appreciably less dense hedgerows. The high soil losses under low crop cover also illustrate again that mulch cover alone (here of only 2 t ha^{-1}) is insufficient in capturing particles. The tree mulch occupies micro-depressions on the tilled soil surface and increases hydraulic roughness, reducing flow velocity, and therefore increases flow depth, while it also protects the soil from impacting raindrops. The hedgerow barriers on the other hand trap runoff water by reducing bare slope length and give runoff water time to deposit soil sediments and infiltrate into the soil.

The competitive effects of hedgerows on crops generally exceed the benefits gained by the answer to land degradation of preventing the often small and only infrequently serious amounts of runoff commonly found in the semi-arid tropics. Nevertheless, cultivation of crops on hill slopes induces unacceptable amounts of soil loss (Stigter et al., 2005), which are commonly prevented by terracing or ditches in the Machakos area (Kinama et al., 2007). The protective function of the mulch being so important, an advice on greater distances between hedgerows can only work jointly with increase of the numbers of trees and/or bringing in additional mulch material from outside the system. Little amounts of mulch, in our case around 2 t ha^{-1}, that generally is accepted as the minimum of making agronomically sense, are known to have a reasonable physical influence, by increasing roughness, on water conservation (e.g. Oteng'i et al., 2007). The results obtained here suggest that it also is a sufficient level for keeping the tolerable soil loss, the maximum erosion for sustainable crop yields, under control (Kinama et al., 2007).

As a system design consequence of these results, provided as an agrometeorological service, frequent rejuvenation of economically preferred hedge rows and greater distances between double or triple rows, in combination with fertilizer use or more mulch, will greatly reduce competition with intercrops. The results learned that to reduce the trade-offs between crop productivity and erosion control on sloping land in the semi-arid tropics is the crux of the matter. It is 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 these strong trade-offs need not be a major deterrent to adoption by farmers, in case grass or trees provide other direct and significant benefits to farmers (Stigter et al., 2005). This are again other aspects of the "farmers first" paradigm in a participatory approach. As to climate change aspects of these agroforestry systems: their protective functions make them even more suitable for conditions with increasing climate variability and more, and more severe, extreme events (e.g. Stigter, 2011c).

GENERATING AND SUPPORTING A RURAL RESPONSE TO CLIMATE CHANGE

The next trend to be discussed is generating and supporting a rural response to climate change in (among others) agrometeorology. We discuss it for agrometeorology using case studies from Indonesia. On-farm knowledge collection will very much help in tying research and teaching to meteorological disaster impact experience and to improved preparedness of farmers in different land use and cropping patterns. An example of the latter is the research we do in Yogyakarta and west Java, Indonesia, stimulating farmers since 2007 to measure rainfall in their fields. Simultaneously they observe crops, soils, water, pests and diseases in this agrometeorological learning. We see this as a start to a rural response to climate change, planning to validate climate adaptation issues (water management, cropping alternatives), using very basic climate information and validating its use or non-use by various farmers (Stigter and Winarto, 2011). This research again very well fits a "farmers first" paradigm in a participatory approach. So far, climate prediction science has, by default, driven the development of climate application tools. Experience over the last decade indicates the need for a user-oriented approach to applications development that is characterized by participatory approaches.

Vulnerable communities across the world are already feeling the effects of a changing climate. These communities are urgently in need of assistance aimed at building resilience and at undertaking climate change adaptation efforts as a matter of survival and in order to maintain livelihoods (e.g. Mergeai, 2010; OXFAM, 2011). They are in need of an urgent rural response to climate change. The reality of climate change calls for a need to understand how it might affect a range of natural and social systems, and to identify and evaluate options to respond to these effects (e.g. Ionescu et al., 2009). This should lead to in-depth investigations of vulnerability and adaptation to climate change, which has become central to climate science, policy and practice. But capacity to conduct vulnerability and adaptation assessments is still limited (Pulhin, 2011).

For example the International Research Institute for Climate and Society (IRI, 2011) indicates to use a science-based approach to enhance society's capability to understand, anticipate and cope with the impacts of climate in order to improve human welfare and the environment. We want to extend this approach to the rural communities of Indonesia and elsewhere. The basis of our approach is listening to the farmers concerned, to better understand their vulnerabilities and needs the way they see them, in a "farmer first" paradigm in a participatory approach, to be able to generate support with them and for them in facing the consequences of increased climate variability and climate change in their livelihoods (Stigter, 2010).

However, applied scientists can not do that all by themselves (Stigter, 2010). They should basically be the connection between applied science (developing agrometeorological services such as maps, forecasts, warnings, design proposals, response proposals etc. etc.) and the actual production environment. To that end these applied scientists would in fact be most useful to back up well educated (in service trained) extension intermediaries to train, on an almost daily basis, farmers, farmer facilitators and ultimately farmer trainers and farmer communities. Unfortunately, extension services are very often virtually absent and where they still do exist they are badly trained and have received little or no upgrading regarding the fast changes that are occurring in the agricultural production environment and about the actual crises in the livelihood of farmers (Stigter, 2011b). This has not yet become a trend anywhere.

In Indonesia experiments have taken place with so called Climate Field Schools (CFSs) (Winarto et al., 2008; Stigter, 2009a; Winarto and Stigter, 2011). This is another new trend, derived from the highly successful Farmer Field School approach. However these CFSs were set up "to teach farmers" instead of having a dialogue on their vulnerabilities, problems and questions. We have noted a gap in "training the trainers" for such CFSs (Winarto and Stigter, 2011).

We finally have experimented with so called "Science Field Shops", in which scientists meet with farmers and the former listen to the latter (Stigter and Winarto, 2011; Winarto and Stigter, 2011). Questions on climate change and its consequences for farmers are answered, vulnerabilities and possibilities/choices/options to tackle them using agrometeorology etc. are discussed. In fact I would like to propose today that a "Science Field Shops" approach would become a new trend in applied agrometeorology and other applied fields of agriculture. If we could start here, we could derive better curricula to “train the trainers” and show how to organize new CFSs to meet the needs of farmers (for agrometeorological services etc.) in their rural response to climate change.

The new agrometeorology of today is what supports those trends:

- Stigter (2010) for services and for the “farmer first” paradigm;
- Winarto, Stigter et al. (2008-2011) for generating and supporting a rural response to climate change; and
- the same literature for a renewal of CFSs, including curricula for “training the trainers”, the extension intermediaries.

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