WIND PROTECTION DESIGNS FROM MEASUREMENTS WITH SIMPLE WIND EQUIPMENT IN FOUR AFRICAN COUNTRIES IN RESEARCH EDUCATION CAPACITY BUILDING PROJECTS

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Abstract

Low external input farmers in Africa suffer from various wind problems. In the research education capacity building project "Traditional Techniques of Microclimate Improvement (TTMI)" carried out at Universities in Kenya, Nigeria, Sudan and Tanzania between 1985 and 2002, several such problems were tackled using simple wind equipment to quantify wind speeds in the agricultural environment concerned.

The research of the authors and their teams proved that appropriate design rules for wind protection could be derived from such simple wind observations, if a sufficient instrument density was chosen, if the instruments were appropriately calibrated in situ and if agrometeorological wind disaster literature was properly reviewed for the design of wind protection.

In Kenya, design rules were derived for a hedged agroforestry system in semi-arid Laikipia. In Central Sudan, design rules were derived for protecting crops from drifting sand by shelterbelts and scattered trees/grasses. In northern Nigeria, the design of multiple shelterbelt systems had to be considerably improved for efficient protection of crops grown between the belts. In northern Tanzania, diminishing soil and crop protection were quantified for decreasing savanna woodland tree densities.

Measurement strategies to represent simultaneous observations of wind reduction with a sufficient instrument density were developed in each country. Ancillary wind information equipment was generated and tested to support such strategies.

Introduction

The TTMI-Project in four African countries (Kenya, Sudan, Nigeria and Tanzania) had between 1985 and 2002 various sub-projects on selected farmer defined priority problems of low external input farmers suffering from disasters caused by wind. Relief measures had to be designed for bringing such problems under control. These sub-projects were research education capacity building projects at Universities and Institutes in Africa that had policies, or were planning such policies, of getting its staff trained in problem solving research with the simple means that could be afforded in the context of the TTMI-Project or otherwise. The need for such work was discussed at TECIMO ten years ago on invitation (Stigter, 1994).

This paper deals with measurements to quantify airflow in the agricultural environment with simple wind equipment, from which wind protection could be designed in these cases. Such problems included mechanical damage, damage caused by drifting sand and hot air related damage. All these examples have been well-documented in peer reviewed journals from 1994 onwards till the present (Kainkwa and Stigter, 1994; 2000; Mohammed et al., 1996; 1999; Stigter et al., 1997; 1998; 2000; 2001; 2002; 2003; 2004a; 2004b; 2005; Oteng'i et al., 2000; Onyewotu et al., 2003; 2004; 2005; Al-Amin et al., 2005), also reviewing wind disaster literature.

Even more importantly, farmers' problems were solved. In all four countries, serious wind protection problems were preventing farming systems to get or remain (re) established. The issue here is the use of basically simple field equipment, in the present case studies to quantify potentially damaging air flow and flow mitigated by protective elements, under remote agricultural field conditions. The focus of this paper is the interpretation of wind measurements for the drawing of design rules for wind protection measures. Can simple wind observations give the right information to take decisions on how to protect crops and soil? The answer for our cases is: yes.

Equipment

In all four countries, a solar powered battery operated data logging system, with wind tunnel calibrated electrical cup anemometers from Wageningen, was applied as basic equipment. The cup anemometer is suitable for this kind of work because it measures all wind components in the damaging and modified flows with an angle of attack lower than 45 degrees. It can be dynamically (re) calibrated outdoors over flat land, if obstacles can be prevented, using an unexposed standard instrument.

The main puzzling issue is a strategy to obtain sufficient observation density to capture particular conditions and details of the flow fields within and around vegetation in space (quasi) simultaneously. What makes these strategies possible is that one is always interested in wind reduction due to protective vegetation. Such relative wind speeds may be obtained on different days as long as the approach wind differs not much in flow direction, flow speed and other flow characteristics.

We will now give four case studies that each delivered design rules from simple wind reduction quantification. In all cases, wind equipment was regularly field calibrated by intercomparisons and data quality was retained in all possible manners. Research education is served this way.

Case studies

Kenya

The first case is about protective hedged agro-forestry in demonstration projects in Laikipia, semi-arid central Kenya. Problems were due to mechanically damaging winds, also redistributing mulch of dry maize stalks used in water conservation. Intercropped trees with hedges all around protected mulched maize/bean intercrops. Root pruning appeared necessary to limit competition.

Wind in the open was compared with an array of measuring points in a hedged area, in which mulch was used on some parts, and that had pruned and unpruned trees for timber production, with maize biomass higher than the hedges. In this experiment wind was always measured 20 cm above the highest maize, the height increasing with time. Main wind directions were varying, from year to year and within seasons, giving different gradients of wind protection from the trees and hedges. The measuring results also revealed the danger of deliberate or natural gaps in the hedges, leading to visibly damaging tunneling effects near gaps (Oteng'i et al, 2000).

An error in the design appeared to be a gap between the highest biomass of hedges and the lowest biomass of trees, endangering maize when high. Another unexpected problem was damage by turbulence generated outside the demonstration plot, which could not be detected by the cups.

The conclusion on these agroforestry experiments, as to the role of simple wind measurements in the redesign of the most suitable protective system, must be considered positive. Although some aspects could have been visibly observed, the quantification with varying wind direction revealed sound details otherwise not detectable (Oteng'i, 2000; Stigter et al., 2002; 2003).

Because of the size of the demonstration plot, instrument density was not a serious problem. Piches as ancillary wind equipment, as earlier reported on at TECIMO (Stigter et al., 1998), were successfully tested under these conditions with small errors remaining due to differences in time constants between cups and Piches (Stigter et al., 2000). Using a reference anemometer from within the agroforestry system improved accuracies considerably.

Sudan

The second case is about drifting sand damage in desertifying Central Sudan endangering the Gezira irrigation scheme. Wind was blowing sand towards canals and crops, which had to be protected by a shelterbelt. Design rules for such shelterbelts were derived from early observations and measurements already reported more than 15 years ago (Stigter et al., 1989). In a follow-up investigation, suitability of selected trees was studied for establishment under simple trickle irrigation, for wind reduction near to the ground and for sand capture and settlement.

In these earlier unique experiments on sand establishment/catching due to wind reduction with an irrigated protective Eucalyptus shelterbelt, that we carried out at Sihaimab between 1985 and 1990, it was shown that in the long run such protective belts had themselves to be protected from sand accumulation (Mohammed et al., 1995). Simple wind equipment had been very useful in these early experiments, including Woelfle anemographs (Mohammed et al., 1999). If multiple shelterbelts are not feasible, only corridors of scattered trees and grasses, that are able to reduce wind sufficiently to catch and settle sand, can bring a solution. Wind reduction and sand settlement by trees and grasses, as a function of their biomass distribution, have then to be quantified in situ (Al-amin et al., 2005).

Measurements of wind reduction were done with arrays of cup anemometers at various heights in front of, behind and at the sides of various tree species and one grass, that had been shown to be sufficiently suitable for establishment under limited irrigation in this desertified environment. The results obtained revealed that medium to high, but not the highest, biomass density closest to the ground, over the largest distance from the tree stem or grass turf center (perpendicular to the wind), and for the largest height, was most efficient for wind reduction and the related sand settlement. The conclusion on these experiments, as to the value of quantification of simple wind profiles for selection of trees & grasses, is moderately positive. Visual observations of patterns of settled sand already revealed a lot on the efficiency of wind reduction. Quantifying wind revealed more on the influence of the biomass distribution.

Nigeria

The third case is about inefficiently established multiple shelterbelts in a desertified part of northern Nigeria. The Kano state Forestry Department planted more than 20 km of multiple Eucalyptus shelterbelts, to combat desertification by settling drifting sand & undulations and this way encouraging the return of soil protecting grasses. Farmers returned to their soils between the belts after the oil boom was over. Shelterbelts were combating desertification well but insufficiently protected crops grown between the belts from hot air. Design rules of better protection and implications for farmers have been discussed (Onyewotu et al., 2003, 2005).

Shelterbelts have been extensively studied with respect to protection of soil and crops from mechanical damage by wind but have nowhere been studied for damage of crops due to hot dry air. It is generally accepted that wind reduction measurements at one height are representative for at least half the height H of such a protective structure. Because the shelterbelts were not equidistant, we chose the narrowest two belts and the nearest large distance belts for belt to belt wind reduction measurements, 20 cm above the highest millet to be expected. This appeared a golden choice, because wind speed returned to close to original values between all belts beyond 5-6 H (Onyewotu et al., 2004).

It was concluded from the wind data, obtained under strong advection, in an unstable atmosphere with low speeds, that actual distances between the belts were too low in all cases and much too low in most cases, even when wind direction had been perpendicular to the belts (Onyewotu et al., 2004). Scattered trees in an increased density parkland would likely have done better (Onyewotu et al., 2005).

Interpretation of simple wind reduction confirmed what yields already showed. In particular the combination of wind data with soil moisture data was very revealing on the dangers of hot dry air movement from before sowing till harvesting. Also homogeneity of permeability could be well quantified by simple wind observations. Increased turbulence due to the belts could not be detected by the cups and it spoiled ancillary wind quantification (Stigter et al., 2000).

Tanzania

The fourth case was on consequences of diminishing tree densities in northern Tanzania for soil/crop protection. Wind reduction in Savanna woodland appeared endangered by felling of trees. Earlier tree densities provided sufficient protection. Simultaneously with the early research on catching sand by wind reduction in front of and inside shelterbelts in Central Sudan, in northern Tanzania this work was done on wind reduction downwind a savanna woodland edge (Kainkwa and Stigter, 1994). These early TTMI wind research undertakings are now appearing in review literature and textbooks as unique examples.

Because of the felling of trees, tree density diminished over three seasons of wind reduction measurements. Data were taken at two heights, 1 m and 2.5 m, both possible crop heights for intercropping between the trees, in long parallel rows of wind instruments that we brought deeper into the woodland each measuring day. There was higher biomass density at 2.5 m and some tunneling at 1 m.

These were also the first experiments were ancillary wind equipment was tried out, that later played an important role in the second generation of wind problems research dealt with earlier in this presentation: Woelfle anemographs and shaded Piche evaporimeters (developed in Tanzania and Sudan) as isothermal air movement indicators. Accuracies were determined. Particularly wind reduction ratios of different instruments were well correlated. Results were widely published (Spaan and Stigter, 1991; Stigter, 1994; Kainkwa and Stigter, 2000; Stigter et al., 2000; 2002).

These results revealed that thinning of savanna woodland had diminished tree densities so much that the soil was finally no longer protected from wind erosion, because wind reduction had lowered appreciably. Other issues were: wind reduction saturation at 50% for still sufficient tree densities, and keeping equal reduction over large gaps, comparable to close enough multiple belts.

As in the other work, important design rules of wind protection by scattered trees could be derived from these simple wind reduction quantifications in the field. Rules on an approximation of necessary tree densities and biomass distributions and on felling strategies, to keep wind reduction sufficiently high, could be derived.

Final remarks

The four case studies illustrate that the use of simple wind equipment can indeed support the appropriate development of design rules for the use of trees in shelterbelts, parkland agroforestry, woodlands and other non-forest situations. It appears possible to develop policies for wind protection, including protection from drifting sand, based on quantitative results locally obtained with relatively simple means, using appropriate quantification densities and strategies.

In capacity building of research education, this demonstrated to African scientists and students what is possible under their research conditions to support policies that may be recommended to authorities for the development of agrometeorological services.

References

Al-amin, Nawal K. Nasr, Kees (C.J.) Stigter, Mutasim A.M. Elagab and Mohammed Bedawi Hussein, 2005. Combating Desert Encroachment by Guiding People, Wind and Sand. Paper presented at the Special Session 1, convened by C.J. Stigter, at the International Symposium on Food Production and Environmental Conservation in the Face of Global Environmental Deterioration (FPEC 2004), Fukuoka, Japan. Journal of Agricultural Meteorology (Japan), 60, in press.

Kainkwa, R.M.R. and C.J. Stigter, 1994. Wind reduction downwind from a savanna woodland edge. Neth. J. Agric. Sc. 42: 145 - 157.

Kainkwa, R.M.R. and C.J. Stigter, 2000. Measuring wind gradients in agroforestry systems by shaded Piche evaporimeters I. Validation of the square-root dependence on wind speed. Intern. Agrophysics, 14 (3): 279 - 289.

Mohammed, A.E., C.J. Stigter and H.S. Adam, 1995. Moving sand and its consequences in and near a severely desertified environment and a protective shelterbelt. Arid Soil Res. Rehabil, 9: 423 - 435.

Mohammed, A.E., C.J. Stigter and H.S. Adam, 1996. On shelterbelt design for combating sand invasion. Agric., Ecosyst., Environ. 57: 81 - 90.

Mohammed, A.E., C.J. Stigter and H.S. Adam, 1999. Wind regimes windward of a shelterbelt protecting gravity irrigated crop land from moving sand in the Gezira Scheme (Sudan). Theor. Appl. Climat., 62: 221 - 231.

Onyewotu, Lambert, Kees Stigter, Yusuf Abdullahi and Joo Ariyo, 2003. Shelterbelts and farmers' needs. LEISA Mag. Low Ext. Input Sust. Agric. 19 (4), 28-29.

Onyewotu, L.O.Z., C.J. Stigter, E.O. Oladipo and J.J. Owonubi, 2004. Air movement and its consequences around a multiple shelterbelt system under advective conditions in semi-arid northern Nigeria. Theor. Appl. Climat., 79: 255 - 262.

Onyewotu, L.O.Z., C.J. Stigter, E.O. Oladipo and J.J. Owonubi, 2005. Insufficient wind protection from hot air by multiple shelterbelts and proposals for improvement. J. Geogr. (China), in press.

Oteng'i, S.B.B., C.J. Stigter, J.K. Ng'ang'a and D.N. Mungai, 2000. Wind protection in a hedged agroforestry system in semi-arid Kenya. Agrofor. Syst., 50: 137 - 156.

Spaan, W.P. and C.J. Stigter, 1991. A review of some simple wind erosion measuring methods and devices. Paper presented at the German Workshop "Quantification of soil erosion by wind", Deutsche Bodenkundliche Gesellschaft (German Soil Society), 33 pp.

Stigter, C.J., 1994. Conditions, requirements and needs for outdoor measurements in developing countries: the case of agrometeorology and agroclimatology. Extended abstract of an invited keynote paper, CIMO technical conference TECO-94, Instruments and Observing Methods Report 57, WMO/TD 588, WMO, Geneva, 1 - 2. [Full text available from WMO or the author, on request.]

Stigter, C.J., C.L. Coulson, A. El-tayeb Mohammed, D.N. Mungai and R.M.R. Kainkwa, 1989. Users' needs for quantification in tropical agrometeorology: some case studies. Instruments and Observing Methods Report 35, WMO/TD 303, WMO. Geneva, 365 - 370.

Stigter, C.J., R.M.R. Kainkwa, A. Eltayeb Mohamed and L.O.Z. Onyewotu, 1997. Essentials and cases of wind protection from scattered trees and shelterbelts. Opening paper in: E.G. Bonkoungou, E.T. Ayuk, and I. Zoungrana, (Eds.), Les parcs agroforestiers des zones semi-arides d'Afrique de l'ouest. [Parkland Agroforestry of the semi-arid areas of West Africa.] SALWA-Network, Ouagadougou, and ICRAF, Nairobi, 232 pp.

Stigter, C.J., R.M.R. Kainkwa, S.B.B. Oteng'i, A.A. Ibrahim, A.E. Mohammed and L.O.Z. Onyewotu, 1998. The shaded Piche evaporimeter as an ancillary isothermal anemometer. Instruments and Observing Methods Report 70, WMO/TD 877, WMO, Geneva, 377 - 380.

Stigter, C.J., R.M.R. Kainkwa, S.B.B. Oteng'i, L.O.Z. Onyewotu, A.E. Mohammed, A.A. Ibrahim and M.G.M. Rashidi, 2000. Measuring wind gradients in agroforestry systems by shaded Piche evaporimeters II. Accuracies obtained in some African case studies. International Agrophysics, 14 (4): 457 - 468.

Stigter, C.J., Ahmed Eltayeb Mohammed, Nawal K. Nasr Al-amin, L.O.Z. Onyewotu, S.B.B. Oteng'i and R.M.R. Kainkwa, 2001. Some African case studies of local solutions to problems caused by wind in smallholder agroforestry. Proceed. 3rd Europe & Africa Conference on Wind Engineering, Eindhoven, The Netherlands, pp. 419 - 426.

Stigter, C.J., Ahmed Eltayeb Mohammed, Nawal K. Nasr Al-amin, L.O.Z. Onyewotu, S.B.B. Oteng'i and R.M.R. Kainkwa, 2002. Agroforestry solutions to some African wind problems. J. Wind Engn. Industr. Aerodyn., 90: 1101 – 1114.

Stigter, C.J., Nawal K. Nasr Al-amin, S.B.B. Oteng'i, R.M.R. Kainkwa, L.O.Z. Onyewotu, 2003. Scattered trees and wind protection under African conditions. In: B. Ruck, C. Kottmeier, C. Mattheck, C. Quine and G. Wilhelm (Eds.), Wind Effects on Trees. University of Karlsruhe, Germany, pp. 73 – 80.

Stigter, C.J., Ahmed Eltayeb Mohammed and Nawal K. Nasr Al-amin, 2004a. Use and suitable designs of shelterbelts and scattered trees as well as grasses for protecting agricultural production and infrastructure from wind driven sand encroachment and expanding desertification. Case study of economically beneficial agrometeorological applications and services and of other success stories in agrometeorology for policy matters. In: W. Baier (Coord.) CAgM Rep. 93, WMO/TD No. 1202, Geneva, Annex 7, pp. 36–39.

Stigter, C.J., L.O.Z. Onyewotu and J.J. Owonubi, 2004b. Combating desertification and reintroducing agricultural production in Sahelian conditions by appropriate planting of multiple shelterbelts and some simple agronomic measures. Case study of economically beneficial agrometeorological applications and services and of other success stories in agrometeorology for policy matters. In: W. Baier (Coord.) CAgM Rep. 93, WMO/TD No. 1202, Geneva, Annex 8, pp. 40 – 43.

Stigter, Kees (C.J.), L.O.Z. Onyewotu and N.K.N. Al-amin, 2005. Wind and Agriculture: an essential subject on the African Participatory Research Agenda. Paper accepted for presentation at the Fourth European & African Conference on Wind Engineering, IAWE, Prague.