

# Iawe International Association for Wind Engineering

## Wind Engineering in Africa

Edition 1 March 2005

### *From the Editor*

This is the first in what I hope will be an occasional series of bulletins produced by the International Association of Wind Engineering. The intention is to stimulate discussion amongst its readers on the application of the techniques and knowledge base of wind engineering to African conditions. I am producing this in my role as the European and African Regional Representative of the Iawe. Should any reader wish to contact me my contact details are as follows.

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In this first edition I include some general information concerning the Iawe, and this is followed by an advance notice of some papers that will be presented at the European and African Regional Conference on Wind Engineering in July this year. The main item in this edition is an article by Kees Stigter on Wind related problems in Africa. In future editions I hope to include some short articles on Wind Energy in Africa and, hopefully, contributions from the readers of the bulletin.

At present I have a reasonably extensive electronic and surface mailing lists – but if readers know of any one whom they feel should receive this and future copies of the bulletin, please let me know.

### *What is wind engineering – and what is the Iawe?*

According to the definition given by Jack E. Cermak (1975), “Wind engineering is best defined as the rational treatment of the interactions between wind in the atmospheric boundary layer and man and his works on the surface of earth”. It is of a multi-disciplinary nature and includes consideration of the following topic – meteorology, wind structure in the atmospheric boundary layer, wind climate, numerical and physical modelling of atmospheric flow fields, bluff-body aerodynamics, vehicle aerodynamics, wind tunnel tests, full-scale measurements, computational fluid dynamics, wind loads on buildings and structures, wind effects on transportation, wind energy production, atmospheric dispersion of pollutants, wind erosion, sand and snow drifting, windbreaks, urban

planning, pedestrian wind environment, natural ventilation, wind actions and effects on long-span bridges, wind-structure interaction, aeroelastic and chaotic phenomena, wind storm disaster assessment and reduction, insurance and re-insurance policies, wind codes and standards, vulnerability of structures under wind loads etc. Clearly some of these topics are not of relevance to African conditions, although many of them will be.

The International Association of Wind Engineering (Iawe) is formed of national and regional wind engineering associations, and has the prime objective of fostering the discipline of wind engineering through the organisation of conferences and seminars, assisting national and regional organisations, making representations to international bodies etc. Organisationally Iawe is divided into three regions – Asia/Pacific, Americas and European/African. The current President is Prof Giovanni Solari from Genoa in Italy.

### *The European and African Conference on Wind Engineering*

The 4<sup>th</sup> European and African Conference on Wind Engineering will be held in Prague, Czech Republic in July 2005. Further details can be found at <http://www.itam.cas.cz/eacwe2005>. Over 200 papers will be presented, but the following will be of particular interest to readers of this newsletter.

Y. Abdellaoui, A. Ouelbani, Y. Gritli, S. Ben Ezzine, M. Annabi Systemic analysis function of automation and regulation of a wind turbine

A. Goliger, Adopting the Euro- wind loading stipulations in South Africa

K. C.J. Stigter, L. O.Z. Onyewotu, N. K.N. Al-amin, Wind and Agriculture: an essential subject on the African Participatory Research Agenda

M. Annabi, Y. Abdellaoui, A. Ouelbani, Y. Gritli, Systemic methodological approach for the analysis of exploitation and development environment of a wind power station

Y. Gritli, A. Ouelbani, Y. Abdellaoui, A. Mami, M. Annabi, Systemic analysis of the functions of conversion and mechanical transmission of an aerogenerator

S. Lefi, C Bouchoucha, A.Ouelbani, M. Annabi, Integration wind power in the Tunisian National Dispatching Centre

J. Wisse A first reconnaissance of climatic wind energy potential in Sub-Saharan Africa

***Wind related problems in Africa - research from the TTMI project***

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## **Introduction**

The Traditional Techniques of Microclimate Improvement (TTMI) Project was core funded by the Netherlands Government at Universities in Kenya and Tanzania from 1985 till 1999, in Sudan from 1985 till 2003 and in Nigeria from 1990 till 2002. It was a research education project in which African Ph.D.-students received their degrees from their own Universities in Africa and were supported by African and Dutch M.Sc.-students doing their research both in Holland and in Africa. In this "picnic" model, the start of the Ph.D.-studies was in Africa, where the most urgent problems were identified by African co-supervisors, their Universities and producers and other decision makers in the African regions in which they operated.

## **Why wind?**

Among those very many priority research subjects identified this way, there were wind problems in Sudan and Tanzania in TTMI-I (1985 - 1991) and in Kenya, Nigeria and Sudan in TTMI-II (1991 - 2003). We have published scores of detailed research and policy papers on each of these problems and a list of these wind-related publications is available upon request. The information in this survey comes from two recent review papers (1, 2).

Smallholder agriculture in Africa suffers at many places from strong and/or desiccating winds. These cause mechanical damage to trees, soils and crops, dry out crops, move protecting biomass around or cause sand to invade crop fields and/or endanger infrastructure, limiting or even prohibiting agricultural production. Trees in agroforestry solutions play an important protective role in solving such problems in Africa. Wind reduction to prevent crop damage and soil erosion can among others be achieved with windbreaks from natural vegetation and bushes or windbreaks/woodlots/shelterbelts from sparse trees or trees in other densities and quantities than forests.

Under African conditions, attention is focused on the influence of scattered trees on wind and its consequences. Such scattered trees in so called agroforestry parklands, or in other tree densities lower or differently arranged compared to those of forests, in addition to protective functions by reducing and modifying air movement also have productive functions. Strong winds are reduced, and this way moving particles are settled, soils are protected from wind erosion, damage to intercrops is reduced. In scattered tree arrangements as well as in design of shelterbelts there is self-protection by front trees facing and modifying the wind speed and its consequences. Air also may carry heat/cold that have less negative impacts downwind when airflow is altered and reduced by trees.

Wind protection of soils and crops from scattered trees, such as in Savannah and other woodlands and agroforestry parklands, has hardly been studied quantitatively. Information on optimum tree and biomass density distributions for various purposes, conditions and localities is therefore badly needed. This is essential in an African Participatory Research Agenda for "wind and agriculture", for microclimate improvement and for protection from all kinds of damages from all kinds of wind speeds and wind characteristics, also including drifting particles. This survey will exemplify the development and

application of design rules for wind protection derived from simple wind measurements and related observations and quantification in the African agricultural environment.

## **The early Tanzanian work: less soil protection in thinned woodland and wind protection of coffee by umbrella shade trees that could not be missed**

The most important conclusions from the wind reduction studies in Tanzania, from a woodland edge into a mainly *Acacia tortilis* Savanna woodland, have to do with the importance of biomass distribution, with respect to the reduction of wind flow, and with the degree of de-coupling of canopy flow and main flow over the woodland. The picture is of course complicated by gusts, and in sparser canopies or at high biomass density gradients, by preferred differences between flow regimes, of which tunneling in the stem space is an obvious example. What is clear from indigenous knowledge and oral history is the reduction of wind protection with the thinning of tree densities in agroforestry parklands and woodlands. The Tanzanian work quantified this.

With a tree density reduced from 150 trees/ha to about 120 trees/ha, wind speeds were at first higher at 1 m height than at 2.5 m, due to a tunneling effect. However, 110 m into the woodland a "saturation wind speed" occurred, that was the same at both heights, at a mean wind speed reduction near 50% of the wind in the open. This "saturation" wind speed, reached in an almost linear decrease from the edge, is a very useful result in matters of soil and crop protection by trees. At 150 till 120 trees/ha, the woodland had a great wind reducing effect.

This had much diminished at 60 trees/ha in the third year of observations, after continuing illegal tree felling, where topsoil started to move and wind erosion then caused loss of this valuable soil. A gap of 50 m had no influence on wind speeds at the above mentioned heights, because the air over the woodland remained de-coupled from canopy flow at these heights to the same degree. These are important results for woodland protection and design.

In the second study in Tanzania we were called upon in an argument between coffee farmers on the slopes of the Kilimanjaro and the local extension services over the necessity to keep traditional shade trees above the coffee. With increasing use of fertilizers on coffee, shade trees can be diminished but farmers argued they wanted to keep them for wind protection against occasional damaging gusts that precede heavy rain showers.

What the farmers experienced appeared to be a diminishing force from strong vertical gusts due to the umbrella shaped *Albizia schimperiana* shade trees. By showing that tunneling horizontal winds were not at all involved in the damage, also not after coffee pruning, visual observations of more damage done to unprotected coffee could be confirmed. The shade trees should be kept and new plantations should be designed with such shade trees in these areas.

## **Early Sudanese work: mechanisms of shelterbelts protecting irrigation canals and crops from accumulating drifting sand, and the derivation of design rules**

Using a traditional method from Egypt, the Forestry administration in Sudan empirically planted irrigated shelterbelts of *Eucalyptus microtheca* spaced at 3 m distance in staggered rows to protect irrigation canals, crops and soil from accumulating wind driven sand encroachment at endangered edges of the Gezira scheme. Factors that should be considered in the design of such wind protection are belt or windbreak

shape, composition, height, length and width, direction, permeability, and, where applicable, distance between belts as well as number of multiple belts. These factors were considered here with respect to the design of single shelterbelts for sand protection. Our quantitative agrometeorology within and in front of the protective shelterbelt led to design rules for such belts.

Separate consideration was given to advice on trees to be used in such 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 airflow 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.

The existing belts were at the time 7 m height and up till 500 m deep. Under the conditions of maximum sand deposition within the shelterbelts, in the first 10 meter near the edge, of about 20 cm per year, the front trees survived the sand deposition. Apparently root development was such that the irrigation water kept reaching the roots of these front trees. Sand was found till about 30 m within the belt. It was estimated that 20 to 30 m would have been sufficient for the width of the belt in these early years but wider belts gave more storage space for accumulating sand. The use of such shelterbelts nevertheless demands for concern about lasting sand deposition that can only be prevented if sand can be deposited/stored and kept in the primary or secondary source areas of the sand.

#### **Follow-up Sudanese work: combating desert encroachment by guiding people, wind and sand using trees, shrubs and grasses**

Because over time sand accumulation could threaten such tree belts as discussed above, using desert vegetation that efficiently reduces wind speed close to the ground, this way settling sand, appears the best solution in a second front against desert encroachment. However, such human induced establishment of trees, shrubs and grasses over large areas appears extremely difficult due to water requirements. Quantitative agrometeorology of wind flow and sand deposition around single trees and bushes, and composite grasses, led to selection of suitable species for use in combating sand encroachment. Keeping sand under control is the price people have to pay for inhabiting these marginal areas that start to become uninhabitable. Four species investigated were worth considering under the conditions of the source areas for sand settlement under windy conditions.

*Leptadenia pyrotechnica* trees/bushes provide good protection against wind erosion and were found to establish well with medium frequent irrigation under the local circumstances and some protection from adverse soil and sand conditions. *Panicum turgidum* grasses are difficult to establish but occur abundantly in the region and are extremely efficient in sand settlement, due to local air flow and sand movement obstruction, particularly when found in clusters caused by its dissociation. "Protection" is therefore the keyword here. *Acacia tortilis* tolerates well the hard conditions of the area, and establishment went reasonably well, but it usually grows into a large tree with little biomass near the surface. However, in reply to our earlier given design rules, it was kept low by controlled grazing by desert dwellers that more recently settled close to the original shelterbelt. The latter is now partly protected from wind driven sand by large-scale development of such low *Acacia tortilis* bushes.

Finally, another debate is that on the suitability of *Prosopis juliflora* (mesquite) trees. With its favourable sand settling properties, given its good biomass distributions for air flow obstruction, and reasonable establishment potential it would be a suitable trial choice in our area if it were not for a government ban on its use, because of its aggressive expansion. But, like in the "*Eucalyptus* debate", what is a disaster in one place may be a blessing under other conditions. With the example of its successful large scale use, together with *Acacia senegal* and grasses, in the El Bashiri oasis in a sand dune fixation project formerly of the UN Sahelian Office, in north Kordofan, this applies to mesquite as well. We are convinced that it should be used near the White Nile also.

*Prosopis juliflora* and *Panicum turgidum* should be further investigated in larger scale pilot projects on the west bank of the White Nile and on the east bank facing the belts, in which projects larger scale air flow modifications may be studied. Other vegetation, like *Leptadenia pyrotechnica* and (if necessary more exotic) vegetation still to be researched should be tried as well. Also the mechanisms through which drifting sand is passing from the west bank to the east bank of the White Nile should be explored, to see whether this sequence can be disturbed. What role does the wind play here? Long term monitoring of wind driven sand arrival in north Kordofan to detect eventual fluctuations in desert expansion is also something to be advocated.

#### **The use of multiple shelterbelts for combating desertification and their insufficient wind protection of intercropped millet in northern Nigeria**

In northern Nigeria, serious desertification occurred in the fifties and sixties due to the usual combination of drought and unadapted land use caused by poverty in low external input agriculture. In long dry seasons the overgrazed sandy soils, where the traditional density of scattered trees mentioned in oral history has strongly diminished over time, were exposed to hot advected air and topsoil loss from wind erosion. Off farm employment in the wake of the oil boom encouraged abandonment of cropland. In the seventies forestry authorities decided to try rehabilitation by the planting of more than 20 km of rainfed multiple shelterbelts, eleven in total, of *Eucalyptus camaldulensis*. This settled drifting sand and the undulations that had formed, and encouraged the return of soil protecting grasses. Off farm employment dwindled and farmers returned to their abandoned land, trying to make use of the improved microclimatic and soil conditions between the belts.

Without access to design rules and as a compromise to the wind directions changing over the seasons, the belts were established at an angle with the prevailing winds, diminishing their wind protective functions in both the wet and the dry seasons. Distances between the belts, in a rule of thumb for protection against mechanical damage advised to be in the order of 10 times the height of the trees, were generally between 15 and 25 times that height. This was a compromise to occupy less farmland, but it kept large parts between the belts unprotected. It was not realized that the main agronomic function of the belts was protection of crops against advected hot air, that visually damaged plants where the quiet zone becomes the wake zone leeward of each belt. The width of the belts was arbitrarily chosen as 30 m, still taking about 20% of farmland, which could have been used better by halving the width and halving the distances between the belts.

At the time of establishment of these belts, participatory approaches were uncommon and the programme is therefore a good example of the problems this caused. Farmers disliked the

farmland being occupied without compensation. Farmers did not like the Eucalyptus trees, because of their aggressive roots and possible allelopathy. While there are scores of indigenous tree species giving food, fruits, fodder or medical products that could have been selected. Farmers were not allowed to do any maintenance management of the belts, such as pruning of the front branches that shade the front rows of crops, or coppicing, that would have delivered fuel wood high in demand. Most farmers therefore resented the belts.

Research, started in the late eighties, showed that root pruning was a necessary precaution to reduce competition between the millet grown and the trees. Farmers had to find for themselves that only close to the belts the crops were sufficiently wind protected. Only much later, our participatory experiments demonstrated why this was the case. At this same very late stage was it shown that root pruning and branch pruning did indeed away with all competition for resources between trees and millet. This showed the maximum benefits of the rehabilitation from desertification as originally designed.

As design rules for the wind protection concerned, together with higher inputs of organic fertilizers, solutions to higher yields should come from (i) better design of multiple shelterbelts, (ii) addition of farmer friendly scattered trees of appropriate densities between too wide belts, and/or (iii) replacement of shelterbelts by systems of scattered trees, so called parkland agroforestry, traditionally in use in the area, but with considerably improved densities. No commitments of that kind have been shown by any extension organization or NGO in the region.

Our research also proved that a scientific determination of sowing time, using on-farm or near-farm rainfall and routine evaporation data, improved yields considerably above those of the traditional methods. On-line determination of planting, using local soil moisture determinations or climate forecasting methods, in so-called response farming, would secure such yield increases. However, no organization of such agrometeorological services appears possible under present day Nigerian extension conditions. Although local adaptation strategies to wind conditions as well as contemporary science to improve them are jointly available, the policy environment is not conducive to useful information transfer. It confirms the view held for now close to 20 years by some political economists that a soil management and rehabilitation policy must be formulated in the context of wider development objectives and a well-defined direction of social change. This is here the context for using more successful design rules of wind protection.

#### **Protection from mechanical damage due to strong winds in a hedged agroforestry system in a semi-arid rain shadow area in central Kenya**

In semi-arid Laikipia, in the rain shadow of Mount Kenya, severe crop damage and loss of blown off mulch material may be caused by strong south to south-easterly winds from June to September. Variable wind direction and interactions between wind and three-dimensional biomass distribution complicate the picture. This is another example of a typically local wind problem, experienced in this case by farmers that were forced to emigrate from higher potential areas in Kenya, because of

population pressure and carrying capacity problems of the land available in their areas of origin. Demonstration farms had to be set up to introduce mulched agroforestry, to make it possible for them to keep growing their maize/bean intercrops to which they were used. The strong winds are experienced during part of the growing season. The following results were obtained:

- it appeared necessary to use *Colleus barbatus* hedges all around the plots to prevent the necessary maize stalk mulches from being blown off the plots. Such mulches here mainly prevent run off of rain water from the plots;
- these hedges had to be root pruned to prevent or at least diminish competition between the trees in the hedges and the crops;
- combining this system with *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, as long as the trees were also root pruned;
- gaps in the hedges could be devastating, due to tunneling and generation of turbulence, if in the direction of prevailing winds, and had to be prevented by all means;
- gaps between the top of the hedges and the lowest biomass of the trees diminished the protection efficiency of the agroforestry system and caused identical dangers;
- turbulence generated by buildings and large trees near to the demonstration plots negatively influenced crop growth locally, indicating the sensitivity of the crops for mechanical wind damage by the winds concerned.

From the above it can be concluded that complex agroforestry systems like designed here for demonstration purposes should particularly take care of the strong influence of three dimensional biomass distributions and their different effects in meandering wind directions.

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, from the design point of view, strong biomass gradients, such as in gaps, as well as generation of additional turbulence that can reach the crop should always be prevented, like this was also the case in the design of shelterbelts.

#### **References**

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