The role of Forest Plantations at Rahad agricultural Scheme in microclimate modification, Case study from Sudan *

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ABSTRACT

This study was conducted at the Rahad Agricultural Scheme (RAS) in Sudan, during the period 2003-2006. The main objective of this study was to investigate the role of forest plantations in microclimate modification and its work as shelterbelts; the following methods were applied to collect data for the study. Experiments were conducted on the Forest Plantations (El Faw Shelterbelts) during the period 2003-2006. Those forest plantations are divided into 19 compartments; the dominant species were *Acacia nilotica, Acacia seyal and Eucalyptus camaldulensis*. It's located West El Faw Town, East El khyari village, South of the main highway road Khartoum- Wad Medani Port Sudan, about three kilometers East of the river Rahad. To assess the impact of Rahad Forest Plantations on wind speed, air temperature, soil temperature, evaporation and relative humidity (RH %) several field measurements were made. Readings during summer and winter were taken to determine the impact of forest plantations on the microclimate and protection of crops from the damage caused by wind. Three compartments were selected to represent the shelter area. The study found that the effect of forest protection extends to 30 H, so the study recommended that, a shelterbelt of one row of trees should be established after 30 H by using *Cajanus cajan,* The area under forests at Rahad Scheme is about 2% of the recommended 5% (the area allotted for forest plantations in RAS), so 3% is recommended to be planted.

INTRODUCTION

The Rahad Agricultural Scheme (RAS) was planned in the early 1970s in response to government's policy for increasing export earnings and assuring food self - sufficiency .It is one of the main four agricultural schemes of

irrigated sub-sector of the central plains of the Sudan. The (RAS) lies east of the Blue Nile on the eastern bank of the seasonal river, the Rahad. It extends between latitudes 13º-7´ and 14º-6´ north, and longitudes 22º-6´ and 35º-9´ east. The scheme is located 160 Km, south of the capital, Khartoum. It is a national project established by the Rahad Corporation Law 1972.(Abdalla, 2002).

15000 tenant growing field crops, horticultural crops, forests and fodders. The Objectives of the Scheme is the Utilization of government investment in water diversion and storage works at EL Rosaries Dam, through crop returns by developing the Rahad scheme. Offering an opportunity to improve further upon irrigation and agricultural technologies. Increase of the quality, quantity and value of the domestically consumed crops. Improvement of the welfare of an economically marginal population, through an increase in their income, standard of living , housing , nutrition , health , education and corresponding changes in attitudes and values. The total areas available for forest activities in RAS are about 16,200 feddans. This constitutes 5.4% of the total area of phase one (300,000 feddans) of RAS (Abdalla, 2006). This forestry area includes reserved area for different forestry planting programmes i.e. firewood plantations (wood lots), shelterbelts and windbreaks, canal side plantations, roadside plantations and small wood lots. These areas are distributed all over the scheme area

The area of the scheme lies in arid and semi-arid climatic zones, RAS is established in the arid and semi-arid climatic zones with maximum temperature ranging from 34 to 42 ºC and minimum 14 to 23 ºC .The relative humidity varies from 21% in April to 70% in August. The rainfall varies between the northern and southern parts of the Rahad Scheme .The northern part has an annual rainfall average just below 300 mm, with a dry period of about eight months, while the southern part has namely phase (1) 300,000 feddans, and phase (2) 520,000 feddans Forest usually reduce the maximum soil temperature and increase the minimum soil temperature with the depth of the soil. The influence of the forest in reducing the maximum soil temperature results partly from the shade of the crowns and partly from the insulation of the forest floor. **(**Abdul, 2003)

MATERAILS AND METHODS

Experiments

Experiments were conducted on the Forest Plantations (El Faw Shelterbelts) during the period 2003-2006.

Those forest plantations are divided into 19 compartments; the dominant species were *Acacia nilotica, Acacia seyal and Eucalyptus camaldulensis*. It's located West El Faw Town, East El khyari village, South of the main highway road Khartoum- Wad Medani Port Sudan, about three kilometers East of the river Rahad. To assess the impact of Rahad Forest Plantations on wind speed, air temperature, soil temperature, evaporation and relative humidity (RH %) several field measurements were made. Readings during summer and winter were taken to determine the impact of forest plantations on the microclimate and protection of crops from the damage caused by wind. Three compartments were selected to represent the main shelterbelts.

. Physical measurements

Meteorological station was established to measure some climatic elements as shown in photo (1).

Meteorological station established at El Faw shelterbelt by the researcher during data collection for measuring some climatic elements.

Wind speed Measurements

The standard instrument used for wind speed measurements by National Weather Services is the anemometer. This consist of a set of (usually three) rigid arms with cups attached, radiating from a central spindle. The speed of rotation of these arms is a function of the wind speed. The number of rotations in a given time can be translated directly into wind speed. Some instruments accumulate the number of rotation for a given period, such as an hour or a day, leading to a measurement of wind run, the amount of air which has passed over the instrument during the period; this is roughly equivalent to the average wind speed during the period. Wind speed and direction vary rapidly with height near the surface of the earth (Peter, 1998).

Anemometer was located in the central part of each compartment (shelterbelt) in windward and leeward 2m above the ground, photo (2).

Photo (2): Cup anemometer, the instrument for wind speed measurement.

Data was recorded every day at 08:00, 12:00 and 16:00; wind speed was measured at different trees height i.e. (3H, 7H, and 11H).

Air temperature measurements

Air temperature was measured three times a day at 08:00, 12:00 and 16:00 at the similar trees height for wind speed measurement, and 16 thermometers were used for measuring air temperature, also small sticks used as stands for thermometers.

Measurements of Relative Humidity.

Dry & Wet bulb thermometers (Asmann) used for measurements of relative humidity at different trees height and three times during the day, i.e. 08:00, 12:00 and 16:00. The measurements have been taken at 2 m above the ground; photo (3).

Photo (3): Dry & Wet bulb thermometers (Asamann), for measuring Relative Humidity, field work records, 2005 (El Faw shelterbelts).

Measurements of Soil Temperature

Soil thermometers 5cm and 10cm depth were used for measuring soil temperature , the measurement have been taken at three time during the day at 08:00 , 12:00 and 16:00 at trees height 3H , 7H and 11H. Photo (4).

Photo (4): Soil temperature measurements, using soil thermometers at different depths, 5cm and 10 cm.

Evaporation measurements

The Piche tube

This is a graduated tube 30cm in length and 1.4cm external diameter. The internal diameter is 1.134cm. A filter paper of diameter 3.0cm is fixed to open end of the tube. A metal disc of diameter 1.6cm is used to support the filter paper. The exposed area of the filter paper is the difference between the area of the filter and the area of the disc .The diameter of filter paper, the tube and the disc are chosen such that a reading of 1cm on the tube corresponds to an evaporation of 1mm.

The piche tube does not measure the evaporation from an extended water surface. It generally overestimates the evaporation. (Adam, 2005).

Piche tubes at height 1m and 2m were used to estimate the amount of evaporation; readings were taken three times at 08:00, 12:00 and 16:00, at different trees height Photo (5).

Photo (5): Piche tube used to estimate the amount of evaporation

RESULTS AND DISCUSSION

The results of physical measurements

Effects of Forest plantations on wind speed

According to the results that obtains from the wind speed measurements during Summer and Winter, 2005-2006, significant differences have been reported . Table (1) and Table (2).

Table. (1). Mean different of wind speed at the study area according to the time and season:

Season	8:00	12:00	16:00
Summer	7.3556 a	7.1222 bb	7.1222 b
Winter	4.314 b	10.657 aa	9.171 a

P= significant

Means with the same letters are not significant different .

Table(2)Summary of the Anova table of the dependent climatic variable

Season	Climatic factors	Anova SS	Mean square	F Value	Pr > F
Summer	Wind speed	0.3267	0.1633	6.03	0.01
Winter		154.0724	77.0362	21.53	0.0001
Summer	Air temperature	315.9674	157.9870	18.71	0.0001
Winter		656.8752	328.4376	233.42	0.0001
Summer	Relative humidity	111.1852	55.5952	7.93	0.004
Winter		1779.8095	24.63	24.63	0.0001
Summer	Soil temperature	210.9170	105.4586	16.42	0.0001
Winter		621.0330	310.5150	51.43	0.0001

Summer	Evaporation	18.4422	9.2211	8.30	0.003
Winter		4.8124	2.4062	8.34	0.005

During winter the highest and lower wind speed have been reported ie: 10.7 km/h at midday and 4.3 km/h in the morning. When wind below, it has positive and negative impacts on plants, soils, and animals. On plants, wind may uproot or break large trees, and a result, some species may be absent from exposed place. Wind has a desiccating effect and hence increases transpiration rates. Two types of wind mass below in Rahad area i:e dry wind during Winter (north- east) and wet humid wind during Summer (south- west) .The dry wind cause damage when a sudden change in wind loading occur , so morphological and anatomical change in plants and trees like deformation and dwarfing . Strange phenomenon at Rahad area was observe , so people suffered from strong wind when the soil is wet (farms are irrigated) , tall crops like Dura and cotton were uprooted and there shapes were changes .

To face the problem, windbreaks and shelterbelts should be establish, because shelterbelts break the force of the air currents and moderate wind speed in areas on the leeside of the wind. How much protection that forest plantations provides depends mainly on its height, porosity (the extent to which gaps let the wind through), vegetation cover upwind and the orientation (the angle at which the wind meets the shelterbelts (forest plantations) .In flat areas , when wind blowing perpendicular to the forest its reduced .When wind strikes a shelterbelts , its velocity is reduced , some of the air passes through and causes minor turbulence , some rolls over the shelterbelt and the remainder is deflected upwards and above it . The ideal shelterbelt filter the wind without blocking completely and the air that passes through the belt emerges on the leeward side at the lower speed . The effect of forest protection extend to 30 H downwind and 5H upwind . So for example a 10 meter height shelterbelt (forest plantations) will provide protection over an area extending perhaps to 300 m downwind . The biggest wind speed reduction occurs in what is known as (quite zone) which may extend to about 12 H downwind .

Wind speed gradually increase in (wake zone) down of quite zone , until the effect of shelterbelt disappeared, see Fig (1).

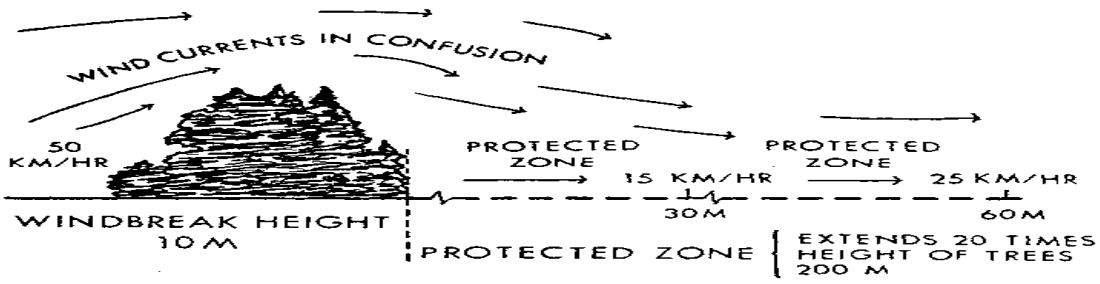

Fig (1): Wind speed reduction, (Aussenac, 1985).

Forest plantations in irrigated agricultural scheme have positive impact and moderate the microclimate behind it . Also crop yield on the leeward of shelterbelt will increase, and people satisfy their needs from food and fodder . Forest plantations reduce the leaf damage , field loss in cereals , lodging (stem breakage or flattening), sandblasting , wind erosion and flower abortion . Reduction in wind speed can prevent adverse physiological changes in crops , such as the reduction in leaf area and photosynthetic rate . also forest plantations provide shelter for livestock ,particularly young animals against the damaging effects of both cold winter and hot summer winds .Strong winds cause damage to houses, roads and human settlements . For the best wind reduction and greatest downwind influence, the windbreak should be most porous near the ground, where the wind speed is lowest. Near the windbreak, wind speed 1m above the plants were barely affected, but in the center of the sheltered area wind speed were reduced by more than 40%. The reduction of wind speed and the reduction of turbulence by a windbreak are not uniquely related. (Brown and Rosenberg, 1 971).

Effects of forest plantations on air temperature

The results of air temperature measurements at Rahad agricultural scheme during summer and winter, agricultural season 2005-2006, showed significant variations during the two seasons, Table (2) and Table (3).

In summer the rainfall increases the relative humidity RH% in the air and decrease the temperature. Forest plantations have an effect on the microclimate behind it , so the protected area is warm during the day and cold during the night

Sudan as a tropical country has a range of high temperature approximately during a whole year.

Table(3) Mean differences of air temperature according to the time and season .

Season	8:00	12:00	16:00
Summer	28.311 b	35.489 a	35.644 aa
Winter	26.0714 c	36.3143 b	39.0714 a
	P=sign	P=sign	

Means with the same letters are not significant different.

In Rahad area the highest temperature was in April when the mean daily is 40c in the open area and 35c mean daily in the shelter area .Air temperature depends on the heat flux balance that caused accordingly to the heating of solar radiation, lost of energy by conduction, convection, advection and latent heat flux.

Air temperature affect plant temperature especially the leaves. The temperature affect negatively the growth and production of an important agricultural crops like maize , it might be more difficult to grow, other crops like rice may not set grain if temperatures become hotter. Wheat production in some areas may decline due to increased temperature. Air temperature affect seed germination, evaporation and evapotranspiration . Forest plantations (shelterbelts) reduce the amount of air temperature on the leeward and moderate air. Farmers, labours , livestock, protected themselves with forest plantations against the hard condition during dry , windy and hot periods . Passengers of Khartoum, Wad Medani, Gedarif , Kassala and Port Sudan use to rest themselves in the Rahad forest plantation because its located near the high way rood. Shading by forest plantations also tends to reduce temperature in the area affected .The conclusion that all meteorological elements act with forests and has significant influence on the Rahad

region and moderate the microclimate surrounding to the forests. air temperature have influence on the distribution on flora and fauna , growth and yield of agricultural and vegetable crops in the Rahad area .

Effects of forest plantations on Relative humidity RH%

According to the results of relative humidity measurements during summer and winter season 2005and 2006 in the study area, a significant differences has been reported (Table (2) and Table (4)), In summer and winter the highest relative humidity occurred in the morning at 8:00 i.e.: 65% in summer and 27% in winter .The increases of relative humidity in summer due to the rainfall, the evaporation rate is lower than in winter and the growth of the vegetation cover.

Table (4) Mean differences of relative humidity % according to the time and season.

Season	8:00	12:00	16:00
Summer	65.333 a	61.33 bb	60.778 b
Winter	27.143 a	8.857 bb	6.571 b
	P=sign	P=sign	

Means with the same letters are not significant different

Forest plantations (shelterbelts), play an important role in microclimate modification. Higher humidity improve the growth of agricultural crops (increase crop productivity), and decrease the rate of plant water use.

During summer (rainy season) when the relative humidity is high the evaporation was less compared with dry winter, appearing of the phenomenon called Guttation will occur in the morning in dura, millet, and wheat leaves.

As stated before RAS located in dry and semi-dry climatic zone, air temperature, wind speed, and evaporation are high. To reduce the efficiency of the above three mention

climatic elements and to increase the amount of relative humidity, forest plantations have a significant affects on the leeward of it and protect the area behind it.

Significant differences between sheltered and unsheltered area will occur at night and in the morning because of the decrease of air temperature in the protected and sheltered area. At midday the relative humidity in forest plantation is more than lee and windward of it .The conclusion that forest plantations in irrigated dry and semi-dry climatic areas have positive impact on the relative humidity in the protected area , decreased the evaporation, and reduced plant water stress.

Effects of forest plantations on soil temperature

As a results of soil temperature measurements, significant differences have been reported between the two seasons (summer and winter) at the different depths (5cm and 10cm), (Table.2, 4 and 5) . The higher soil temperature in winter at depth 5cm was 34.8c , while 31.2c is reported in summer at the same depth. The lower soil temperature was reported at depth 10cm , i.e. 32.1c in winter and 29.3c in summer.

Table (5). Mean differences of soil temperature between summer and winter according to the depth .

Season	Depth (cm)	Mean
summer	5cm	31.1778 a
	10 cm	29.2519 b
winter	5cm	34.7714 a
	10 cm	32.0571 b

Means with the same letters are not significant different.

Table (6) Mean differences of soil temperature according to the time and season.

Season	8:00	12:00	16:00
summer	27.6333 c	30.5778 b	32.4333 a
winter	28.9500 c	32.9571 b	38.3357 a
	P= sign	P= sign	P= sign

Means with the same letters in one season are not significant different.

From the result, soil temperature was differ during the day according to the time and depth. Soil temperature acted like other climatic parameters; it affect the soil depth, soil moisture, the physical structure of soil, and vegetation cover (forests and shelterbelts).The change of soil temperature near the forest plantations occurred according to reduction of evaporation. When wind passes over the soil surface , the surface moisture is evaporated and this will creates a cooling effect and reduce the soil temperature . Soil temperature in protected and sheltered area is slightly warmer than in unsheltered area . (table .6) , showed that soil temperature with deeper level indicates a downward flux of heat into the soil . Differences in energy balance due to differences in weather was reported .The energy reaches the earth surface is small compared to that of the atmosphere and it becomes even less in the forest plantations when absorbed by the canopy .

The effects of forest plantations on evaporation

Evaporation is the loss of water from open bodies, such as lakes, reservoirs, rivers, wetlands and bare soil, but transpiration is the loss from living plant surface. Several factors other than physical characteristics of the water, soil and plant surface are affecting the evaporation process. the more important factors include solar radiation , surface area of open bodies of water , wind speed , density and type forest plantations , availability of soil moisture , root depth, reflected land surface characteristics and season of year .According to results of the evaporation measurements at (RAS) during summer and winter 2005and 2006, significantly differences have been reported , Table 2 and 7. The

day time affect on evaporation rates i.e. in summer and winter at 8:00, 12:00 and 16:00 the variation is more clear.

Table (7) Mean differences of evaporation according to the time and season .

Season	8:00	12:00	16:00
summer	3.8222 b	5.744 a	4.2333 bb
winter	4.8714 b	5.8571 a	5.9143 aa

P=sign P= sign P=not sign

Means with the same letters in one season are not significant different.

In summer and winter the high rates of evaporation reported at midday (12:00), because of increases in air temperature, decrease of soil moisture and decrease of relative humidity.

Wind speed is considered an important climatic factor that contributes to evaporation and evapotranspiration by bringing heat energy into an area and removing the vaporized moisture .The type of vegetation cover e.g forest plantation have an affect on evaporation from wet land (irrigated farms). The relationship between wind speed and evaporation was very strong, because high wind speed increases the evaporation rates from soil.

Minimum evapotranspiration rates generally occur during the coldest months (winter) , and maximum rates which generally coincide with summer season when water may be in short supply , also depend on the availability of soil moisture and forest maturity .

For irrigated sectors, the average annual evaporation varies greatly, it depends on the grass or crop type, quantity of water applied, and length of growing season .The conclusion that in dry and semi- dry climatic zones where the study area was located, forest plantations (windbreaks) have important role in reduction of evaporation rates .They have positive effects on the quality of the environment, because they can clearly change the microclimate and the local ecosystem.

CONCLUSION AND RECOMMENDATIONS

Conclusion

1- The effect of Forests (shelterbelts) extends to 30 H.
2- In zone (2), Quiet zone, crop yield reported higher productivity compared with zone (1), competition zone and zone (3), wake zone.

Recommendations

-The effect of forest protection extends to 30 H, so the study recommended that, a shelterbelt of one row of trees should be established after 30 H by using *Cajanus cajan*

- The area under forests at Rahad Scheme is about 2% of the recommended 5% (the area allotted for forest plantations in RAS), so 3% is recommended to be planted.

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