Spatial and temporal variation of soil temperature of *Taxodium Distichum* Shelterbelts in south China

Lu Zhang$^1$, Ding Ma

College of Forestry and Landscape Architecture, South China Agricultural University, Guangzhou, 510642, China

Email: zhanglu@scau.edu.cn

**Abstract.** With the global environmental change, more attention was paid to the effect of farmland shelterbelt. In this study, spatial and temporal patterns of soil temperature in shelterbelts of *Taxodium distichum* in South China was monitored using gradient observed method through observation plots placed in *Taxodium distichum* shelterbelts, sugarcane field and blank field (open site) in January, April, July, and October, respectively. It was found that soil temperature changed with time in a day with a single peak in all the four phases among three sites. However, compared with blank field, the vertical patterns of soil temperature of *Taxodium distichum* shelterbelts and sugarcane field showed special characteristic. One-way ANOVA and Tukey’s HSD showed soil temperature was significantly different with annual and seasons among *Taxodium distichum* shelterbelts, sugarcane field and blank field along a seasonal dynamic ($P < 0.05$). Effective measures should be taken to regulate the soil temperature in order to satisfy the needs of growth of sugarcane.

1. Introduction

Farm land shelterbelt are believed to provide a number of ecosystem services and environmental benefits [1], which is well recognized for reducing soil erosion [2], increasing diversity [3] and has gained attention because of its perceived potential to sustainably enhance agricultural production [4]. Three-Norths Forest Shelterbelt program was carried out in 1970s to combat desertification and control dust storms in China, and various shelterbelts have been constructed in China today. Studies were mainly concentrated on air temperature and relative humidity [5], soil temperature [6], photosynthetically active radiation [7], soil carbon dioxide flux. There was a remarkable difference in the soil temperature between a broadleaved - Korean pine mixed forest and its adjacent open site in Northeast China, and the forest had a lower soil temperature than the open site when the soil temperature was above 0 °C, but was in adverse when the soil temperature was below 0 °C [8]. The soil temperature of forest is one of the important environmental factors of forest ecological system. However, as a managed ecosystem, soil temperature in farmland shelterbelt has seldom been reported.

In this paper, we investigated the temporal variation of soil temperature and the site difference at farm shelterbelts of *Taxodium distichum* in South China. The objectives of our study were: (1) to examine the temporal variation and vertical patterns of soil temperature among *Taxodium distichum* shelterbelt, sugarcane field and blank field, and (2) to compare the annual and seasonal differences of soil temperature among three sites, and discuss the reason if the difference was significant.
2. The study areas
The study area is located at the Lile town of Jiangmen (112° 47′ 13″ - 113° 15′ 24″ E, 22° 05′ 43″ - 22° 48′ 24″ N) in the southern part of Guangdong province, South China. The main zonal soil is Lateritic red soil. The area is characterized by a subtropical continental monsoon climate, which is hot in the summer. The mean annual temperature is 21.8 ℃, and the mean annual precipitation is 1784.6 mm. Three sampling sites (Taxodium distichum shelterbelt, sugarcane field, and blank field) were located at the Lile town. The dominant species of the study area is Taxodium distichum, Taxodium ascendens, Glyptostrobus pensilis, and Livistona chinensis.

3. Methodology
Using gradient observation methods, soil temperature of the shelterbelt microclimate on both horizontal and vertical scales were measured with surface thermometer (WQG-15) and angle geothermometer (WQG-16) through observation plots placed in Taxodium distichum shelterbelts, sugarcane field, and blank field, respectively. Our field monitoring was conducted in four phases, i.e. January, April, July, and October. The soil surface temperature, the soil temperature under soil layer 5 cm, the soil temperature under soil layer 10 cm, the soil temperature under soil layer 15 cm, and the soil temperature under soil layer 20 cm were measured in the four phases. Each phases choose typical weather continuous monitoring for three days, 12 monitoring days in total. Statistical software program was employed for One-way ANOVA to compare temporal differences of soil temperature among Taxodium distichum shelterbelts, sugarcane field, and blank field.

4. Results and discussion
4.1. Temporal patterns of soil temperature
Soil temperature changed with time in a day with a single peak in all the four phases, i.e. January, April, July, and October, which was higher in the afternoon and lower in the early morning and evening (Figure 1). The peak temperature of three kinds are all at the time of 14:00 in January. However, in July the peak temperature of blank field is much easier than the other two. Soil temperature of blank field was the highest, while the soil temperature of Taxodium distichum shelterbelts and sugarcane field were the lower in all the four phases. Moreover, the soil temperature of sugarcane field was higher than the soil temperature of Taxodium distichum shelterbelts in July and October, while the soil temperature of Taxodium distichum shelterbelts was higher than the soil temperature of sugarcane field in January. The mean daily soil temperature was 24.1 ℃, which was 0.9 ℃ and 5.6 ℃ lower than that of sugarcane field and blank field. Patterns of daily soil temperature change in Taxodium distichum shelterbelt in January were similar to that in sugarcane field, whose diurnal ranges were lower than that of blank field. As compared to sugarcane field and blank field, Taxodium distichum shelterbelts had a significantly greater cooling effective in July and October, while the soil temperature changes with time not so dramatically in January.

Hydrothermal conditions of the forest is the result of nutrient and energy exchange between shelterbelts and the environment. Our findings showed that Taxodium distichum shelterbelts mitigated soil temperature in July. Results show that the shelterbelt can increase the soil temperature of the protected farmland as compared with no shelterbelt zone at regional scale based on MODIS data [9]. Our Study revealed that soil temperature of different monitoring time of the day of Taxodium distichum shelterbelts was lowest, while blank field’s was highest in July. For example, average soil temperature of Taxodium distichum shelterbelts in July was 29.9 ℃, which 11.0 ℃ lower than the same period of blank field. For all year, in the forest the soil temperature were lower than on the blank field. On the one hand, it is available to plant seed germination and survival, on the other hand lower soil temperature provides a stable external environment for soil microbial, and conducive to soil organic matter decomposition and nutrient enrichment10. From this standpoint, shelterbelts not only
play its ecological barrier function, but also had great significance for the local plants grow, regulating local climate and optimizing the environment.

4.2. Vertical patterns of soil temperature
Vertical patterns of soil temperature of *Taxodium distichum* shelterbelt, sugarcane field and blank field exhibited an inconsistent pattern. Compared with soil temperature of blank field at the ground > soil temperature at 5 cm depth > soil temperature at 10 cm depth > soil temperature at 15 cm depth > soil temperature at 20 cm depth, the vertical patterns of soil temperature of *Taxodium distichum* shelterbelts and sugarcane field showed special characteristic (Figure 2). Soil temperature of *Taxodium distichum* shelterbelts at 5 cm depth was the lowest, with the increase of depth, soil temperature increased in January and October. That is because the soil of *Taxodium distichum* shelterbelts at 0 cm - 5 cm depth had already from exotherm to endotherm, while the soil at 10 cm - 20 cm depth had remain exotherm at that time. Soil temperature of *Taxodium distichum* shelterbelts at the ground > soil temperature at 5 cm depth > soil temperature at 10 cm depth > soil temperature at 15 cm depth > soil temperature at 20 cm depth in April and July.

Meanwhile, the vertical patterns of soil temperature of sugarcane field was similar to *Taxodium distichum* shelterbelts in January and October, except for soil temperature in different depths were lower than *Taxodium distichum* shelterbelts. This may be associated with higher groundwater level of sugarcane field. Soil temperature of sugarcane field at the ground > soil temperature at 5 cm depth > soil temperature at 10 cm depth > soil temperature at 15 cm depth > soil temperature at 20 cm depth in July. It's worth pointing out that soil temperature of sugarcane field at the ground < soil temperature at 10 cm depth < soil temperature at 15 cm depth < soil temperature at 20 cm depth < soil temperature at 5 cm depth. This may mainly by the artificial factors, such as tillage, fertilization of sugarcane field in April, which may be related to tillage, fertilization and so on of sugarcane field in Spring. Meanwhile, vertical soil temperature of sugarcane field lower than that of *Taxodium distichum* shelterbelt, which be connected with underground water level and artificial irrigation. In addition to the influence of climate, artificial measures had greater effect on the vertical change of soil temperature.

4.3. Annual and seasonal analysis of soil temperature
One-way ANOVA show that annual patterns of soil temperature were significantly different between *Taxodium distichum* shelterbelt, sugarcane field and blank field (P < 0.05). Tukey’s HSD test revealed that mean annual soil temperature were significant differences between *Taxodium distichum*
shelterbelts and blank field. But, mean annual soil temperature had no significant difference in sugarcane field and in blank field, and soil temperature had no significant difference in sugarcane field and in *Taxodium distichum* shelterbelts too (Figure 3).

![Figure 2. Vertical variation of soil temperature](image)

![Figure 3. Annual analysis of soil temperature](image)

Soil temperature of *Taxodium distichum* shelterbelt, sugarcane field and blank field exhibited a same pattern: soil temperature of July > soil temperature of October > soil temperature of April > soil temperature of January (Table 1). However, seasonal patterns of soil temperature were different among *Taxodium distichum* shelterbelt, sugarcane field and blank field. One-way ANOVA show that seasonal patterns of soil temperature of *Taxodium distichum* shelterbelt, sugarcane field and blank field had no significantly different between any two of the three sampling sites in January (*P* > 0.05). Seasonal patterns of soil temperature were significantly different between any two of the three sampling sites in April (*P* < 0.05). Tukey’s HSD test revealed that there were significant differences between sugarcane field and blank field, however, there was no significant difference between *Taxodium distichum* shelterbelt and sugarcane field, and between *Taxodium distichum* shelterbelt and blank field. However, seasonal patterns of soil temperature were no significant difference between *Taxodium distichum* shelterbelt and sugarcane field in July and October.
Table 1. Seasonal analysis of soil temperature

|        | January | April  | July   | October |
|--------|---------|--------|--------|---------|
| Forest | 17.1±0.5 a | 24.2±0.5 ab | 29.9±0.5 b | 25.1±0.3 b |
| Sugarcane | 17.0±0.5 a | 22.8±1.1 b | 34.0±1.5 b | 26.8±0.6 b |
| Blank  | 19.7±1.5 a | 26.6±1.0 a | 40.9±2.6 a | 31.5±1.9 a |

Mean ± S.E. followed by the same letter is not significant at 0.05

5. Conclusion
Our study found that at the 0 – 20 cm depth the daily and the annual ranges of soil temperature were lower in the Taxodium distichum shelterbelts and sugarcane field than that of the blank field which outside of the vegetation. The vertical patterns of soil temperature of sugarcane field was similar to Taxodium distichum shelterbelts in January and October. It's worth pointing out that soil temperature of sugarcane field show a special characteristic by influence of human factors in April. Artificial measures had greater effect on the vertical change of soil temperature. Soil temperature was significantly different with annual and seasons among Taxodium distichum shelterbelts, sugarcane field and blank field along a seasonal dynamic (P < 0.05). However, patterns of seasonal variation between different habitats in soil temperature characteristic were different. Cooling effect of Taxodium distichum shelterbelts is obvious in South Subtropical Region, which was a dominant factor driving the temporal variability of soil temperature in growing seasons of sugarcane.

Acknowledgement
In this paper, the project supported by the Science and Technology Planning Program of Guangdong Province (Project No. 2013B020305009) and Guangdong Natural Science Foundation (Project No. 2015A030313403).

References
[1] Zhang L H, Chen Y N, Zhao R F and Li W 2012 Eur. J. Soil. Biol. 48 24-31
[2] Brandle J R, Hodges L and Zhou X H 2004 Agroforest. Syst. 61 65-78
[3] Gámez-Virués S, Gurr G, Raman A, Salle J L and Nicol H 2009 Biocontrol. 54 211-218
[4] Ding S H and Su P X 2010 Agroforest. Syst. 80 117-129
[5] Zhang L, Su Z Y and Wang X L 2013 Adv. Mater. Res. 610-613 1150-1154
[6] Sindhu S S, Sunjea S, Goel A K, Parmar N and Dadarwal KR 2002 Appl. Soil Ecol. 19 57-64
[7] Mõttus M, Ross J and Sulev M 2001 Agr. Forest Meteoro. 109 161-170
[8] Sun J W, Wu J B, Guan D X, Wang A Z and Yuan F H 2011 Chin. J. Ecol. 30 2685-269
[9] Deng R X, Li Y and Zhang S W 2011 J. Forest. Res. 22 65-70