Plant Archives Vol. 21, Supplement 1, 2021 pp. 731-735 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
doi link : https://doi.org/10.51470/PLANTARCHIVES.2021.v21.S1.110

ROLE OF FORESTS IN REGULATION OF CLIMATE AND CROPS PRODUCTIVITY

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ABSTRACT

The study on the relationship between the global forest areas and global warming testifies about the possibility of negative climate change reduction through the afforestation, as forests can efficiently utilize one of the main greenhouse gases–carbon dioxide (R^2 – 0.8464). Steep increase in the global air temperature is also associated with critical level of deforestation on the global scale. Notwithstanding the fact that forests play an important role in ecosystems and climate regulation, it was found that it is difficult to establish any significant influence of forests on the productivity of some major crops on the example of Kherson oblast, Ukraine. However, it was determined that if the pace of deforestation in the mentioned region keeps up, it is highly likely that the area will be at risk of complete deforestation and transform into arid desert until 2050th. Therefore, the steps for afforestation should be taken both on the global and local scales to prevent further deterioration of climate conditions and keep global warming under control.

Keywords: Afforestation, climate change, deforestation, global warming, greenhouse gases.

Introduction

Forest is a valuable part of biosphere and ecosystems. However, modern anthropogenic activities, together with adverse natural factors, have led to significant decrease in the world forest areas. Much damage has been done to forests and adjacent ecosystems in the recent decades due to the great leap in the world population. It is expected that anthropogenic load on the forests has not reached its peak yet, and it will continuously increase, resulting in greater diminishment of the forests areas, forest poor conditions, and deterioration of ecological conditions of the biosphere in general (Kimmins, 2004, Newton, 2007), as forests are one of the valuable regulators of micro- and macroclimate and provide numerous species with a place of habitat (Hunter and Hunter Jr, 1999).

One of the main concerns related to the intensive deforestation is its connection to current global warming – significant increase in global air temperature that is mainly put upon the increase in greenhouse gases concentration (Ramanathan, 2007), which in its turn adversely affects agriculture and food security due to the increased frequency of droughts, weather abnormalities, freshwater scarcity, soils deterioration, and, as a result, crop losses (Arnell *et al*., 2019). As far as we know, forests are effective natural absorbers of CO_2 and can help in the control of greenhouse gases concentrations in the atmosphere (Houghton *et al*., 2015). Therefore, it is an important task of modern science to determine the role of forests in the restriction of global warming both on the global and local scales together with establishing the reaction of major crops to deforestation. Finding out the mentioned links should provide reasonable information on the needs (or absence of them) for afforestation to enhance crop productivity and control the raise of air temperatures.

The goal of the study is to determine: i) the connection between the world forest areas and global air temperature; ii) the connection between the world forest areas and global greenhouse gases concentrations; iii) the connection between the forest areas in Kherson oblast (Ukraine) and the yields of major crops in the region; iv) provide a substantiation for taking steps in afforestation or prove the evidence that there is no need for this measure as some scientists claim (Wang *et al*., 2015).

Materials and Methods

The study was performed both for global and local scale. The local scale part of the research was dated for Kherson oblast, the South of Ukraine.

The study is based on the statistical retrospective data provided by FAO (global forest areas from 1990 to 2015), NOAA/ESRL (for greenhouse gases concentrations), Berkeley Earth datatsets (for global air temperatures), Ukrainian State Statistical Service (for the yields of cereals, sunflower, vegetables and potato in Kherson oblast), Kherson Regional Statistical Service (for the areas of forest in Kherson oblast). The data from the mentioned sources on forest areas, greenhouse gases, crop yields were generalized and processed using statistical tools of BioStat v7 and Real Statistics add-in for Microsoft Excel.

Statistical processing of the data included Pearson's correlation analysis (Benesty *et al*., 2009), linear regression analysis, trend analysis (Seber and Lee, 2012), Mann-Kendall and Sen's slope test, performed with accordance to internationally accepted methodology (McLeod, 2005). The forecast of forest area in Kherson oblast was performed using exponential smoothing algorithm in Microsoft Excel 365 (Hyndman *et al*., 2008). All statistical calculations were performed at $P<0.05$.

Results and Discussion

Deforestation, global air temperature increase and carbon dioxide concentration rise are not debatable phenomena in the modern world. To support the statement, we provide the results of Mann-Kendall and Sen's slope test (Table 1).

Deforestation could be one of the reasons for intensive warming of climate, especially, if we will consider the interconnections between the global forest areas and greenhouse gases concentrations and, as a result, air temperatures (Fig. 1-2).

There is a mutual link between deforestation and climate change: climate change to some extent causes deforestation (because of fires, insects and disease infestations, which occur more frequent in the conditions of global warming), and at the same time, deforestation is one of the reasons for further changes in climate on the local and global scales (Seidl *et al*., 2017).

The analysis of the relationship between forest area and greenhouse gases concentration, main of which are carbon dioxide, methane, nitrous oxide (Baede *et al*., 2008), has testified about the great role of forests in combating against further increase in the figures: the less forest area is, the greater greenhouse gases concentration is, because the remnants of forest cannot efficiently utilize the excessive amounts of the gases emissions (Table 2).

As the data of Table 1 testify, the strongest interrelation is recorded between the forest area and carbon dioxide, while the least connection is related to nitrous oxide. However, carbon dioxide is a predominant greenhouse gas, therefore, forests significantly decrease the total greenhouse gases concentration in general, resulting in better ecology and anti-warming effects.

However, some studies claim that afforestation effect on the mitigation of global warming are debatable, and it mainly would be effective only in tropics, while the effects would be insufficient or even adverse in higher latitudes and temperate climate (Bala *et al*., 2007). At the same time, there is another opinion, supporting the results of current study, that deforestation, in particular, in tropics, will cause strong adverse effect on warming on the local and global scale, resulting in simultaneous aggravation of agriculture conduction (Lawrence and Vandecar, 2015). Besides, deforestation also has adverse effects on soils, water objects, biodiversity, etc., resulting in alteration of the global natural balance (Houghton, 1990). For example, adverse effects of deforestation on soils are increased bulk density, decrease in the content of organic matter, worsened chemical and mechanical properties (Hajabbasi *et al*., 1997).

The regulation is true on the local scale either. There is an evident trend to deforestation in Kherson oblast (the South of Ukraine, semi-arid climatic zone). Forest areas in the region decreased from 130,700 ha in 2005 to 73,700 ha in 2018, or by 43.60%, with a trend to further decrease (Fig. 3). On the other hand, it was determined that there is a strong trend to an increase in the yields of vegetables and potato in Kherson oblast (R^2 = 0.9188), while there are just slight tendencies in the yield dynamics for cereals (R^2 = 0.3747) and sunflower (R^2 = 0.4538).

The result of Mann Kendall and Sen's slope test also testifies about the fact of reliable trend to the increase in the yields of cereals, sunflower, vegetable crops and potato under the simultaneous decrease in the forest area in the studied region (Table 3).

Therefore, if the trend in the diminishment of forest area will be saved, we are at risk of complete lost of the forest in the region until 2052-2054 (Fig. 4). Such an unpleasant perspective can also increase the pace of aridity increase in the region, particularly, considering its current aridity levels and raise of the air temperatures, which are reported in the works by Vozhehova *et al.* (2020), Lykhovyd (2018).

As for the forest areas in the studied region, there is a tendency to gradual decrease in the areas covered with forests and forest shelterbelts, resulting in the worsening of microclimate of the region. Besides, diminishing of forest areas has an influence on crops productivity, especially, on vegetables and potato, which is testified by the values of coefficient of determination (R^2 = 0.31). However, this reaction is slight enough to be considered as a decisive factor of productivity. At the same time, cereals and sunflower are insensitive to deforestation, and provide no reaction on the mentioned decrease in the forest areas (R^2 = 0.08 both for cereals and sunflower). Therefore, we found out that there is no strong evidence for negative or positive effects of forest areas on major crops productivity in the studied region, notwithstanding the fact of microclimate impacts of deforestation on global and local scales.

There are just a few studies devoted to direct and indirect impacts of forests on crop production. Although the fact that forest is an irreplaceable part of ecosystem and plays a great role in many biological regulations, there is a lack of direct evidence for its affection on crop yields, as it was proved in our study. But we cannot deny the fact that forests take part in soil fertility formation, water resources storage and distribution, weather regulation, etc. (Pearce, 2001), and all the mentioned factors, to some extent, have a direct impact on the crops' productivity. For example, it was also proved that deforestation and run down forests are one of the reasons for a decrease in the productivity of the crops, which are entomophylic and require insects-pollinators, most of which lost their habitat in the forests, for the yield formation (De Marco and Coelho, 2004). Although we established the presence of inverse correlation between the yields of major crops and the forest area in Kherson oblast, it is quite debatable that the trend to yield increase would have remained if agricultural techniques for crop production had not changed drastically to the side of intensification. In addition, it should be mentioned that forests fulfill a great role in the climate change, especially, in the air temperatures regulation, and, therefore, they cause an indirect impact on the crops productivity, but it is difficult to detect, pick out and quantify this effect because of complicated system of interconnections in the agroecosystems (Kosolapova and Vasbieva, 2011).

Conclusion

The results of the study convince us that current state of the global forest calls for taking urgent steps for afforestation. Afforestation is highly likely to reduce the rate of growth of the global air temperature owing to absorption and utilization of greenhouse gases, which are believed to be

one of the major reasons of climate change, for mainly carbon dioxide, and many times less – methane. While nitrous oxide concentrations must be regulated using other options, because presumably it cannot be efficiently utilized by forests.

Notwithstanding the fact that forest plays an important role in climate regulation, it is impossible to find any reliable connection between the crop yields and forest areas. We can put this fact upon the steep development of agrotechnologies in the recent years, and agrotechnological inputs, which were not taken into account in the study, distorted the picture of the forest's impact on the crops' productivity.

The situation with deforestation in Kherson oblast is critical, because if no steps to stop this process are made, there will be no forest in the region until the 2050th.

Table 1: Mann-Kendall and Sen's slope test results for the global forest areas, air temperature and carbon dioxide concentration

Mann-Kendall test			
Index	**Forest area**	**Air temperature**	**Carbon dioxide**
alpha	0.05	0.05	0.05
MK-stat	-347	199	325
s.e.	47.95	45.37	45.37
z-stat	-7.22	4.36	7.14
p-value	5.35×10^{-13}	1.28×10^{-5}	9.23×10^{-13}
trend	yes	yes	yes
Sen's slope			
alpha	0.05	0.05	0.05
slope	-0.04	0.03	1.93
lower	-0.04	0.02	1.88
upper	-0.03	0.04	2.00

Table 2: Relationship between forest area and greenhouse gases concentration

Coefficients	**Carbon dioxide**	**Nitrous oxide**	**Methane**	**Greenhouse gases in general**
Pearson's correlation coefficient R	-0.92	-0.27	-0.76	-0.91
Determination coefficient R^2	0.8464	0.0729	0.5776	0.8281

Table 3: Mann-Kendall and Sen's slope test results for the yields of crops and forest areas in Kherson oblast

Mann-Kendall test				
Index	**Cereals**	**Sunflower**	**Vegetables + Potato**	**Forest area**
alpha	0.05	0.05	0.05	0.05
MK-stat	43	39	79	-73
s.e.	18.27	18.27	18.27	17.97
z-stat	2.30	2.08	4.27	-4.01
p-value	0.02	0.04	1.95×10^{-5}	6.17×10^{-5}
trend	yes	yes	yes	yes
Sen's slope				
alpha	0.05	0.05	0.05	0.05
slope	0.10	0.04		-520
lower	0.02	0.01		-1059.13
upper	0.20	0.07		-296.88

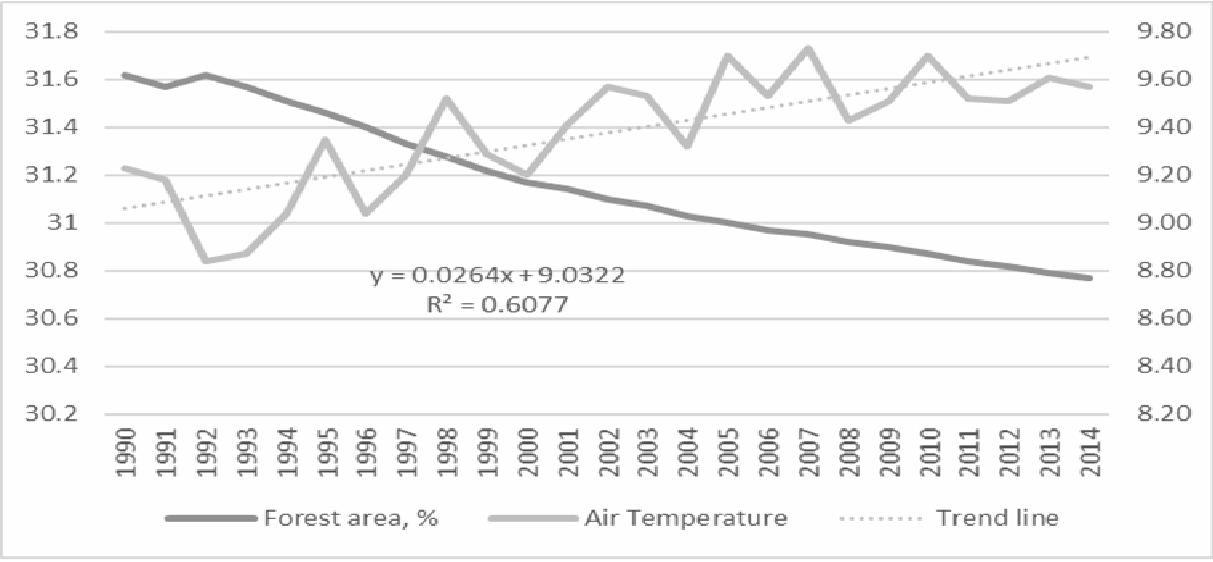

Fig. 1: Forest area and global air temperature (1990-2015)

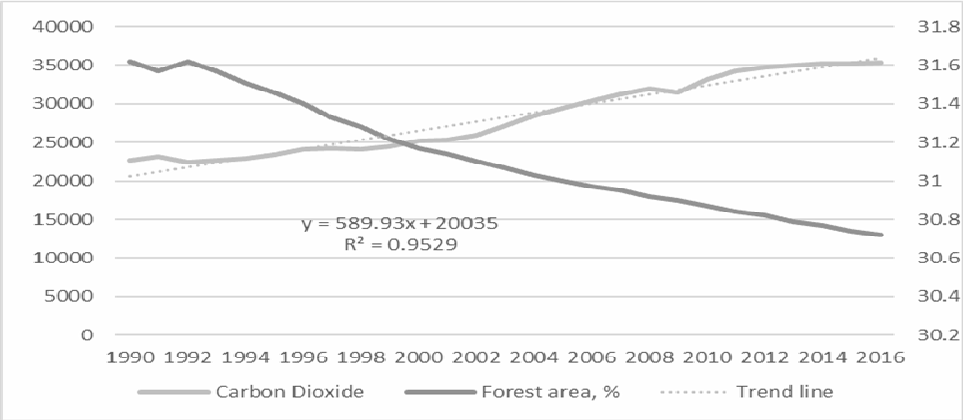

Fig. 2: Forest area and carbon dioxide concentration (1990-2016)

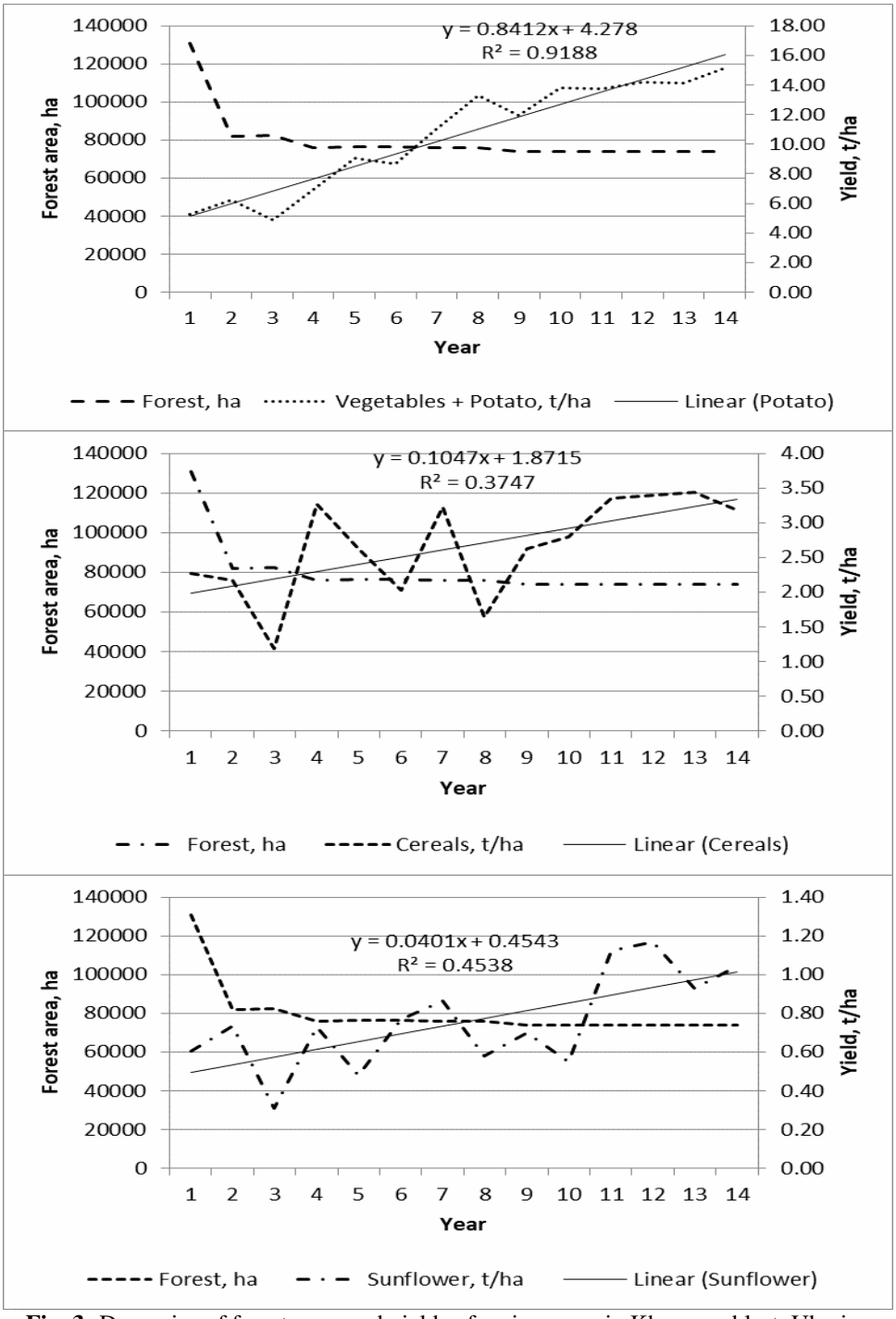

Fig. 3: Dynamics of forest area, and yields of major crops in Kherson oblast, Ukraine

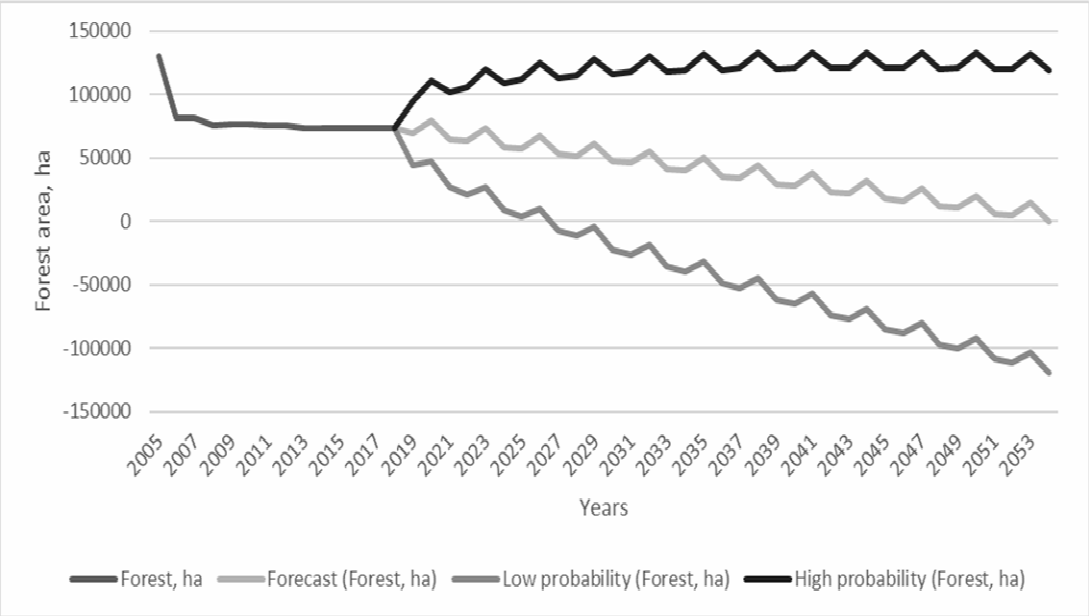

Fig. 4: Forest area forecast for Kherson oblast

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