AGRO-TOURISM IMPACT ANALYSIS OF CLIMATE CHANGE USING GOOGLE EARTH ENGINE IN THE RAHOVEC WINE REGION OF KOSOVO

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ABSTRACT:

Climate change is a global problem and has a major impact on the economy of the developing world. The use of open data and modeling provides a considerable resource for governments, municipalities, and NGOs to develop an understanding of how climate change will impact their communities. This paper discusses the statistical concepts used to model MODIS Land Surface Temperature dataset and calculation of water balance with interpretations of the results. The results of this paper will utilize open datasets, an analysis of the impacts of temperature changes on the developing tourist economy in the Republic of Kosovo, and the knowledge of the capacity for leveraging large geographic datasets for open climate change research. The data from this paper shows a high level of vulnerability to viticulture in Kosovo due to significant trends in water balance and land surface temperature trends within the Drini I Bardhë basin and the future impacts of this on the regions wine agro-tourism by understanding the development of climate change in the region.

1. INTRODUCTION

The use of big data and open modeling provides a considerable resource for governments, municipalities, and NGOs to develop an understanding of how climate change will impact their communities. The paper discusses the statistical concepts used on the MODIS complete dataset and interpretations of the results. The major concepts approached are the use of Google Earth Engine utilization for modeling remote sensed data to understand the environmental conditions being caused by climate change in Kosovo. The underlying data analysis and implications draw connections within local conditions and how human environmental conditions are impacted for wine tourism development. The results of this paper will utilize open datasets, an analysis of the impacts of temperature changes on the developing tourist economy in the Republic of Kosovo, and the knowledge of capacity for leveraging large geographic datasets for open climate change research.

Viticulture heavily influences the economy of Mediterranean Europe due to suitable environmental conditions. However, climate shifts are expected to decrease the suitable viticultural lands by 25% to 73% by 2050 under the current CO_2 emissions pathway, with Southern Europe becoming heavily reliant on expanding viticulture into new lands with a slow decay of productivity and quality within old wine regions. Climate change is expected to negatively impact higher quality wine production in some growing regions due to extreme heat damaging the biological and agricultural systems, including drought. These issues are linked with vine-based agro-tourism development.

To understand the impacts of climate change on wine grape capacity, water balance is utilized as a function. The attempt is to functionally understand the future disruptions of climate change through linear geographic regressions, which will guide the understanding of the climate changes that are occurring with the country and provide a basis for analysis to develop resilience methods. This model will be broken down into viticultural regionality to understand the dynamism of the impacts across the country.

MODIS land surface temperature and Tropical Rainfall Measuring Mission will be used as two datasets to create an understanding of surface temperature shifts within Kosovo and water balance shifts that are occurring due to climate change in Kosovo. The datasets will be correlated between each other and analyzed using a Pearson's correlation coefficient to understand if a relationship exists between land surface temperature and water balance within the wine region of Kosovo.

The findings of this project will reveal geographic dispersion of anomalous rain patterns and long-term temperature shifts occurring that can have disruptive impacts on agricultural production of grapes. The results will provide insights based on the known geographic extent of wine grape region to determine the significant temperature changes occurring over the past 20 years and the trends for both Day and Night land surface temperature within the Republic of Kosovo. Further, the analysis will seek to develop an understanding of the immediate to long-term impacts based on the satellite data trends.

Water balance data analysis will provide precipitation shifts that are occurring on a monthly basis and can be assessed with land surface temperature as a means of understanding areas that are susceptible to flood-based natural hazards and amplification through increased temperatures and loss of water balance. The connection between the two can be assessed to understand systemic

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vulnerabilities occurring within regions that require environmental quality for success.

This project is a novel framework for time series analysis of big data to provide insights into climate change impacts on the economies of the developing world. The analysis will focus on the geographic dispersion of touristic economy assets that are being built and improve the use of big data approaches to derive an understanding of temperature changes in data-poor environments. The results of this paper will leverage open datasets, an analysis of the impacts of temperature changes on the developing tourist economy in the Republic of Kosovo, and the knowledge of the capacity for leveraging large geographic datasets for open climate change research.

The goal of this project is to assess the impact of these variables that might occur and the degree of coupling between them (Kleidon et al., 2013). This will be done through the trend assessment of the data and if there is a correlation between these dataset trends. We seek to understand the influence and environmental coupling of land surface temperature and water balance, as both concepts are connected within the water cycle.

2. MAIN BODY

2.1 Site and Situation (Study Area):

The Republic of Kosovo is a relatively new country having been declared independent in 2008 and has had very little time to develop adaptive strategies for climate change mitigation. Kosovo has experienced low water resource availability, with storage capacities of only 300 m³ /person compared to a 799 m³ /person Balkan regional average, and extremely poor water resource management plagued by systemic and systematic corruption (Government of the Republic of Kosovo, 2019; World Bank Group, 2018). Compared to other countries in the region, the levels of rainfall and the renewable resources per person are much lower. It is estimated that Kosovo has about 1,600 m³ total renewable water resources per person per year, which is about 16 percent of the regional average. Water is stressed and unevenly distributed in time and space. This distribution means that currently adequate resources are available in the Drini I Bardhë and Plava basins, the other three basins indicate water stress and increasing the stress towards the Drini I Bardhë. Kosovo's water storage is underdeveloped (World Bank Group, 2018).

Kosovo is particularly vulnerable to climate change due to its limited renewable water resources and storage capacity. Several medium-sized to large reservoirs that are utilized for water supply, agriculture, industry, and hydropower generation were built in an effort to partially solve hydrologic restrictions (Government of the Republic of Kosovo, 2017; World Bank Group, 2018). Kosovo is extremely susceptible to summer droughts, which is made worse by the lack of any inflows save for the Ibër and any storage. In the past 20 years, Kosovo has experienced drought on multiple occasions (1993, 2000, 2007, 2008, and 2014). The 2007 droughts were especially severe. Several rivers, including the well-known Mirusha Waterfalls, dried up. The driest month ever recorded in Kosovo was February 2014, according to records (World Bank Group, 2018). Since 2008, 80% of the municipalities in Kosovo have faced water shortages due to hydrological droughts. Due to average temperatures increasing every year, Kosovo has seen increasingly more cases of droughts and wildfires (Government of the Republic of Kosovo, 2019).

Droughts will continue to be a major issue within the Western Balkans as temperatures are expected to continue to increase by 4°C by the end of the century, with immediate warming over 1.2°C occurring now. The wine region and the larger Drini i Bardhë of Kosovo is expected to experience the extreme extent and intensity of very hot summers while experiencing extreme snow cover loss and extreme increase in very heavy precipitation (Vuković and Mandić, 2020).

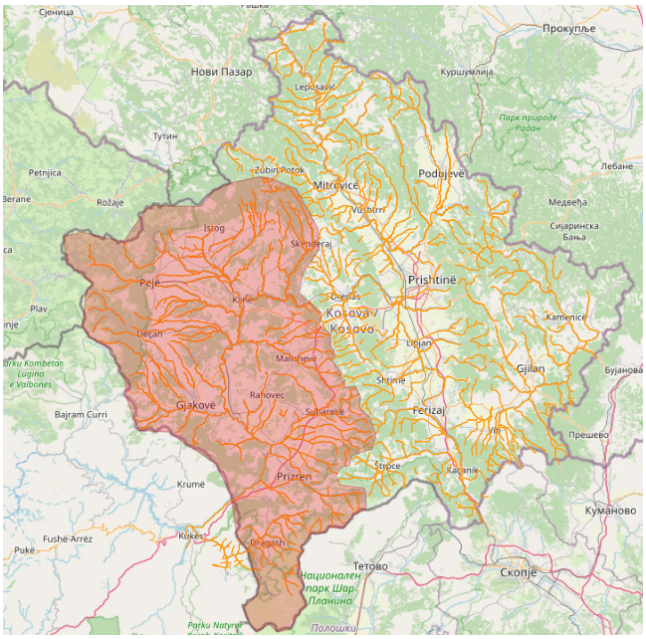

Figure 1. The Drini I Bardhë Basin and the Republic of Kosovo

2.2 Methods:

2.2.1 Modis Land Surface Temperature was calculated using MODIS product MOD11A2.006. The near daily 1KM data utilization for this project spans from 2003 to 2021. The data was aggregated into 8-day averages as a USGS MODIS product. A time band is created to allow for trend analysis. Cloud masks were applied to remove clouded pixels and a data validation threshold was set to >95% (Wan et al., 2021). The data is converted from emissivity to land surface temperature (LST) using a normalized difference vegetation index (NDVI) on an 8day/1km basis using simple average (Wan et al., 2021). The project utilizes the nighttime land surface temperature dataset due to the climate change propensity towards heating nights at higher rates and the nature of grape development impacts with nighttime temperatures.

This allows for a greater understanding of how temperature changes are impacting grape vine productivity. A P value of 0.05 was selected for the Mann-Kendell test.

Land surface temperature is a measure of radiance values received and is calculated using MODIS Emissivity band 31 and 32. MODIS imagery is provided by two satellites Terra and Aqua that are in sun-synchronous orbits with global twice daily revisit rates. Terra crosses the equator at 10:30am and PM. Aqua crosses the equator 1:30am and PM (Clinton and Gong, 2013). Pre-processing that occurred from the MOD11A2.006 image collection uses a Generalized Split-Window (GSW) algorithm that corrects for atmospheric effects based on the absorption of adjacent infrared bands (Tang et al., 2008).

Land surface temperature is a method of remote sensing the derivative thermal values expected for specific areas, given the large data set utilization through MODIS provides a very robust trend analysis to better estimate and understand the community adaptation or maladaptation to climate stress forcing.

2.2.2 Water Balance and Drought is a calculation of the hydrological system of which is influenced by several inputs; precipitation (P) which encompasses rainfall and snow. The system's extractions occur through runoff (Q) and evapotranspiration (ET), which encompasses the combined processes of evaporation from the land surface and transpiration from plants. Finally, Changes in groundwater and soil storage, known as water balance, are indicated by ΔS (Poortinga et al., 2023).

Water balance is defined as:

$$P = Q + ET + \Delta S, \quad (1)$$

Where P =precipitation

Q = streamflow

ET = evapotranspiration

ΔS = change in storage

Precipitation estimates are from the CHRIPS Pentad: Climate Hazards Group InfraRed Precipitation with Station Data of which is a method of estimation of precipitation using thermal infrared and station weather data to produce high resolution precipitation data (Funk et al., 2015).

Evapotranspiration MOD16A2 is an evapotranspiration product produced at 500 m resolution and input daily meteorological reanalysis data in combination with MODIS to produce the estimate.

Soil moisture index (MSI) = SWIR / NIR (Yue et al., 2019):

$$MSI = \frac{SWIR}{NIR}, \quad (2)$$

The analysis of water balance and drought was conducted using a model produced by Poortinga et al., (2023), which was recast on the Drini I Bardhë basin in the western region of Kosovo. Water balance analysis is used to understand water resources in a hydrological system.

2.2.3 Mann-Kendall Test:

Test Statistic:

$$Z - MK = \begin{cases} \frac{E[S]-1}{\sqrt{VAR\,(S)}}, & E[S] > 0 \\ 0, & E[S] = 0 \\ \frac{E[S]+1}{\sqrt{VAR\,(S)}}, & E[S] < 0 \end{cases}, \quad (3)$$

Where the mean=

$$E[S] = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_1 - x_j), \quad (4)$$

And the Variance =

$$VAR\,(S) = \frac{1}{18}(n(n-1)(2n+5) - \sum_{k=1}^{p} qk(qk-1)(2qk+5)), \quad (5)$$

The Theil-Sen estimator is a non-parametric trend analysis that provides an unbiased estimator for true slope within a simple linear regression. The Sen's Slope allows for an estimation of trend significance within a directionality and when run concurrently with a Man-Kendell gives a better understanding of geographic data trends for land surface temperature by assessing the changes occurring in the dataset through time.

2.2.4 Sen's Slope Estimator:

$$= median\left\{\frac{x_j - x_i}{j-i} : i < j\right\}, \quad (6)$$

Manipulation of this equation allows for a developed understanding of various aspects of the hydrological cycle. The model output informs understanding towards the sustainability of water within the Drini I Bardhë and how climate and environmental impacts will inform water availability in the wine region.

The final statistical method utilized is the Pearson Correlation Coefficient. This statistical analysis was utilized to assess the possible level of coupling by assessment of correlation between land surface temperature and water balance. The correlation allows for an understanding of the impact of land surface temperature on water resources, allowing for a better understanding of the influence thermal trends will have on the Drini I Bardhë River Basin.

2.2.5 Pearson Coefficient:

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y - \bar{y})^2}}, \quad (7)$$

Where:

r = correlation coefficient

x_i= values of the x-variable in a sample

$\bar{x}$= mean of the values of the x-variable

y_i = values of the y-variable in a sample

2.3 RESULTS:

Overall, the results agree with climate change estimates for water balance reduction and temperature rise.

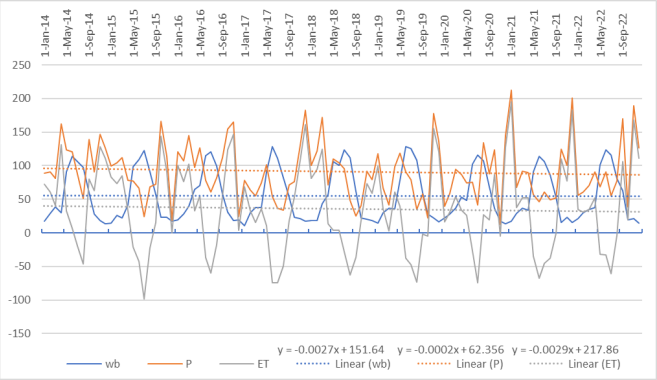

Figure 2. Drini I Bardhë River Basin Results for monthly water balance (wb), preciptiation (P) and evotranspiration (ET) from 2014 until 2022 with trendlines.

Figure 2 shows the water balance, precipitation, and evapotranspiration for the Drini I Bardhë basin. This graphic represents the water basin function with counter balancing evapotranspiration and water balance during the summer and coinciding synergy between the two during winter. This provides an 8-year window in the current trend of the water basin. Monthly analysis of water balance, precipitation, and evapotranspiration for the Drini I Bardhë basin shows multiple changes over the study period between 2014 and 2022. Data for precipitation shows increasing variance using a chi-square test which follows the expected trend of climate change with increased anomalous impacts on weather causing overall reduced precipitation this follows in Figure #2 with reducing overall precipitation but increased anomalies in the dataset. This trend is visible within the basin analysis with increased intensity precipitation occurring at longer intervals.

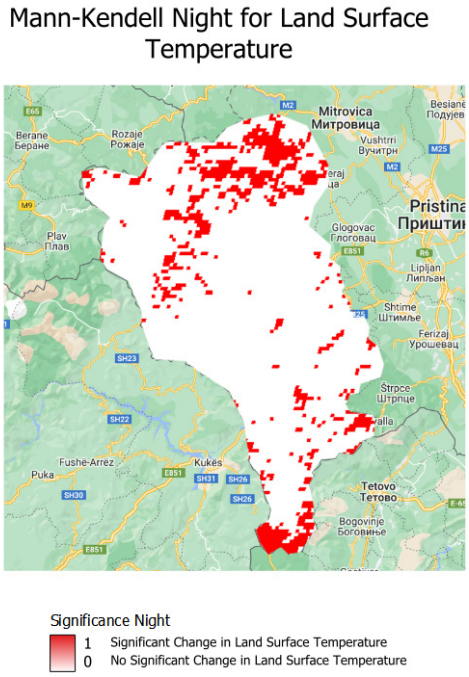

Figure 3. NIGHT LST Mann-Kendell Results

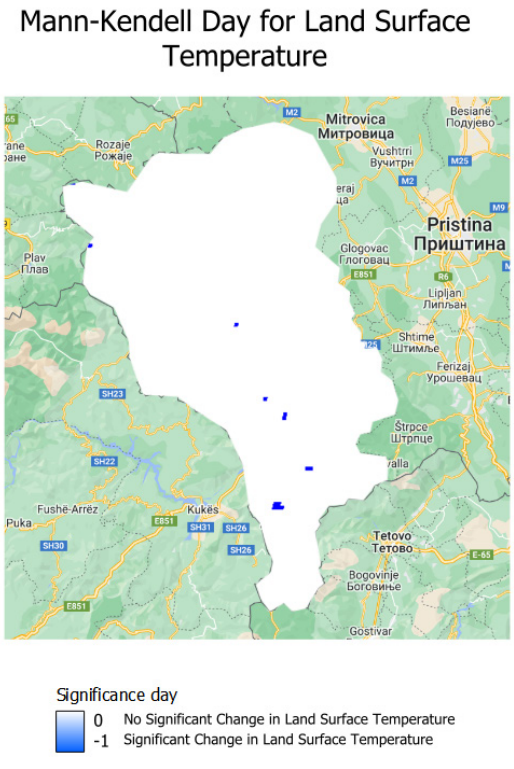

Figure 4. Day LST Mann-Kendell Results

This contribution has been peer-reviewed.
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Day LST shows significantly decreasing trends south of Prizren but saw largely no significant changes.

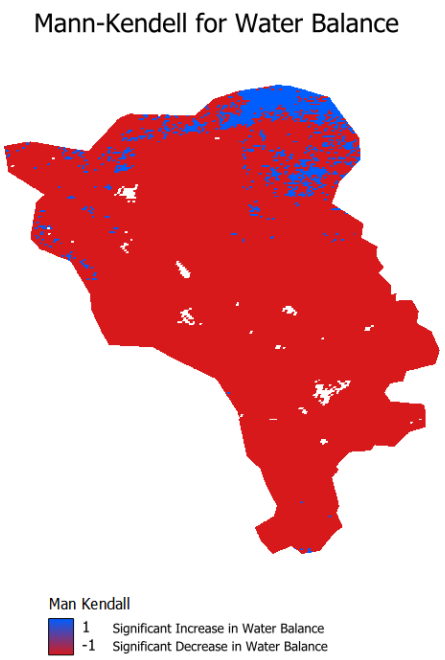

Figure 5. Mann-Kendall Water Balance

Water balance was significantly declining across the basin with significant increases in water balance occurring on the mountainous regions along the Northern Borders with some positive trends occurring on the northeast of the study area.

Figure 6. Night LST Sens Slope

Day LST Sen's slope revealed a mixed blend of increasing and decreasing temperatures across the study area. Many regions with increasing temperatures are areas of urbanization.

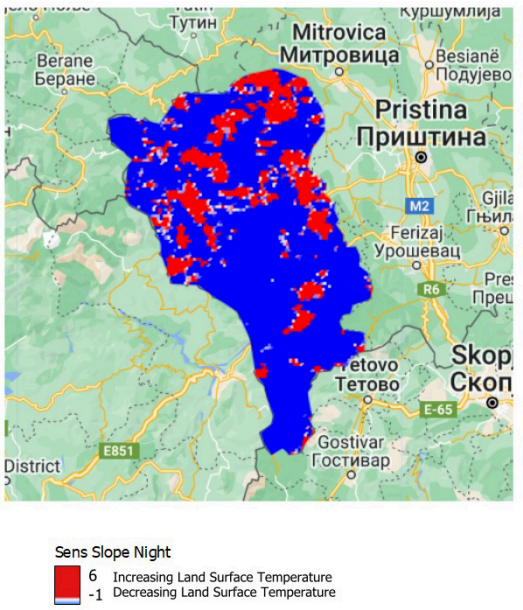

Figure 7. Day LST Sens Slope

Night LST Sen's slope revealed nearly entirely increasing temperature trends across the study area, with some areas showing decreases in trends.

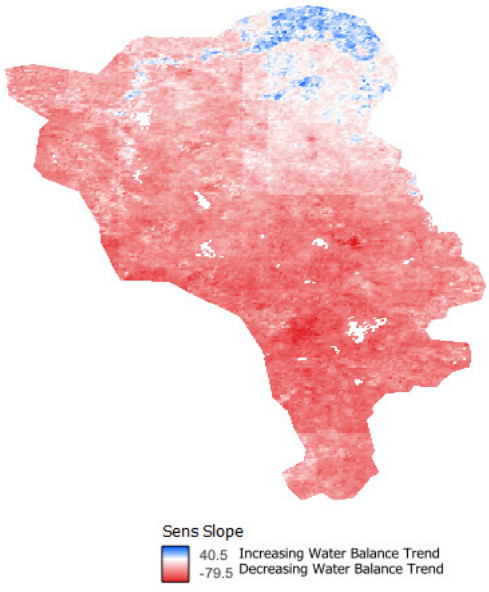

Figure 8. Water Balance Sens Slope

Sens Slope for water balance shows trends towards decreasing water balance across the basin with the Northeastern portion seeing positive trends.

Pearson Coefficient:

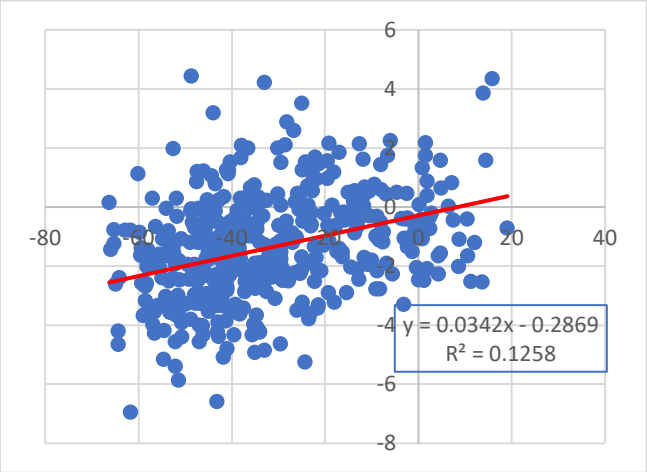

Figure 9. Pearson Correlation Coefficient between Day Land Surface Temperature and Water Balance

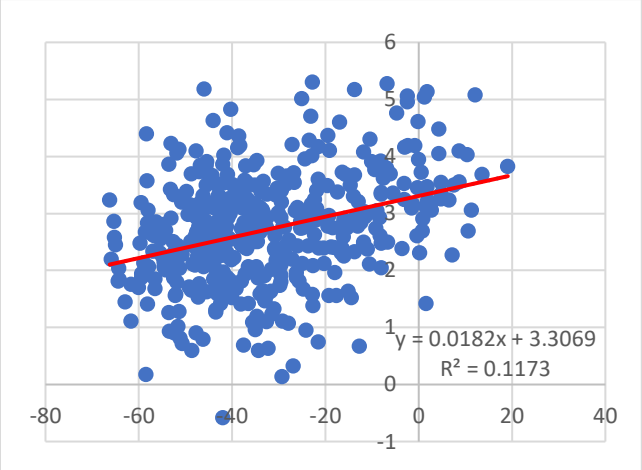

Figure 10. Pearson Coefficient Night Land Surface Temperature and Water Balance

The Pearson Correlation Coefficients for both Day and Night LST showed a weak positive correlation with Water Balance.

2.4 DISCUSSION

There are significant land surface temperature changes for both water balance and night land surface temperatures for Kosovo. The problem of freezing has historically been avoided in Kosovo and expected climate shifts in the region are towards increasing temperatures, though development of hail and other weather anomalies is a significant issue revealed in interviews (Spiridonov and Valcheva, 2019). Climate shifts in Kosovo are expected to see a rise in temperature by ~3°C with higher expected values depending on the vineyard geography with an estimated -16% change in overall precipitation (Cardell et al., 2019). Globally warmer growing regions such as California are projected to see wine grape crop yields rise by 90% in coastal regions with extensive CO_2 fertilization for nitrogen balancing (Ashenfelter and Storchmann, 2014). Whereas the expected outcome and current trend is that increased CO_2 fertilization, pesticide and fungicide spraying, and irrigation will be required to maintain productivity as lands become marginalized due to climate change. Cooler region crop yields will be increasingly endangered due to synergist impacts of diseases and warmer temperatures. The modeling also reveals significant night land surface temperature changes in the mountainous regions that make up the Northern and Southern Border for Kosovo, this region is also experiencing a significant upward trend in water balance and is occurring due in part to forest suitability increasing into higher altitudes due to climate change. This is where an inverse trend occurs where significant increasing land surface temperatures also coincides with significant positive trends in water balance.

Hypothetically these two models correlate in that the increase of land surface temperature has an impact on the hydrological cycle through direct impact of various aspects of water balance. This is revealed through the Pearson's data as having a weak positive correlation for both Day and Night land surface temperature and water balance. The coupling between emissivity and water balance is therefore a weak positive coupling, in which both datasets trend together but appear to have the same response to climate change in the Drini I Bardhë Basin. This reveals the complexity of regional water resources and the importance of further hydrological research towards understanding the impacts of climate change on Kosovo. The water balance graph displays trends over the last 8 years in which there has been a massive decline in water balance and evapotranspiration in the basin itself. This is a function of climate change; there will be more water at random periods of time, as seen in the graph on the right side. The orange precipitation line has higher peaks, there is a massive change in precipitation at important time periods. Recent years (2019, 2021, 2022) have seen increases in rain compared to the average, but the evapotranspiration is happening over the longer period of time. This is a basic function of climate change. Interviews with farmers reveal that water availability is less reliable. Flooding and drought cycles are more extreme and poorly timed compared to the needs of the plants. This is reflected in the research displayed in Figure 2 which indicates that the basin itself is experiencing highly anomalous rain events with large amounts of water being added to the basin in very short periods while also experiencing reduced overall water balance. This coincides with other water models that revealed a reduction in overall precipitation with an increase in water anomalies for the Drini I Bardhë Basin (Sanchez et al., 2023).

The lack of surface water storage in this basin coupled with the modified evapotranspiration results in increasing erosion, stripping the land of its nutrient value, creating harsher soil. Declines in water balance across the basin are most likely related to the water retention capacity of soil in response to the rapid shrink/swell cycles, which overall increases erosion across the basin causing marginalization of the land. This negatively impacts the wine industry severely. Too much water logging increases the disease proliferation, causes multiple issues for nutrient deficiencies, and increases the probability of vines becoming vectors of disease. Many of these environmental issues will culminate in extremely favorable conditions for pests; in particular the *Scaphoideus titanus* (leafhopper), which will act as vectors for the phytoplasmatic disease *Flavescence dorée phytoplasma* (FDp) ravaging vineyards across Kosovo (Gjinovci et al., 2022). The spread of FDp and the proliferation of *Scaphoideus titanus* occurs due to poorly maintained vineyards in marginalized lands, such as the region of study, and spread into adjacent healthy vineyards.

Not enough water when they need it reduces yields and quality of the grapes produces issues across the board. This perpetual water imbalance leads to increasing marginalization of land, which will likely lead to economic loss in the agrotourism industry if not mitigated.

Water management will be vital for future mitigation of climate change impacts. Constructed wetlands would improve moisture retention when there isn't enough rain and forces moisture into the soil when there is too much rain. This team has pursued a theoretical case study for the hypothetical construction of wetlands to explore this possibility and will be explored further in the future.

This region will require a wide range of tactics to improve the management of this problem. The hostage state condition of Kosovo has set the country back in its ability to manage their land and prepare for climate change in the future. There is little to no stewardship or land conservation that will need to be developed to reach a point where they are close to improving the conditions of this land and retaining their livelihood associated with agriculture. The dependance of the economy building agritourism is heavily tied to this necessity. Properly managing this situation will improve the long-term stability and development of Kosovo in the future.

The economic outcomes of viticultural production are heavily linked to climate given the extreme sensitivity of grapes to anomalous weather, diseases, and pests. More diverse wine markets can expect large variation in wine pricing due to grape changes from to anomalous climate impacts that are not well understood on a global level (Sommer et al., 2015). Wine pricing can vary by 20 to 1 from year to year by the sample plot of land due to condition shifts that disrupt the ripening process or yield capacity (Ashenfelter and Storchmann, 2014). The quality of land selected will greatly impact grapes' ability to survive climate stresses especially vineyards planted on marginal lands and native species with susceptibility to climate change. Highly fertile lands, which are largely cultivated in Kosovo, will provide protection against climate change but will still suffer economic disruptions caused by shifts in terroir (Jones et al., 2012). Extreme weather disruptions will heavily impact vine productivity and longevity if not mitigated properly.

2.5 CONCLUSIONS

The Republic of Kosovo is working towards developing many touristic economic sectors that are heavily reliant on climate including the wine regions of Rahovec and Prizren, both of which face tremendous uncertainty in the face of climate change. These issues are exacerbated by a lack of expertise within local, regional, and national government systems due to scarce resources and largely outsider interpretations of climate change.

The data from this paper shows a high level of vulnerability to viticulture in Kosovo due to significant trends in water balance and land surface temperature trends. A valuable correction for this is the adaptation of engineered wetlands on vineyards becoming marginalized due to climate change. The scale and scope of grants required to manage this adaptation is likely too high for the developing nation to deliver and importantly the cost of this adaptation increases with the further increases of these trends. The damage of climate change will require re-education of farmers towards sustainable methods with better understanding of how climate change is currently and will continue to impact them. This includes knowledge building of researchers on open data applications to understand climate change in the young vulnerable Republic.

Development of tools and technics to display the capabilities of open data analysis and provide vital analysis into the impacts of climate change. We have shown the capability for utilization of open-source datasets, to build open-data models capable of providing vital insights into the impacts of climate change in countries that have the least resources and the most risk. This risk is extremely high in vulnerable agricultural sectors such as viticulture.

In data-scarce environments, this method of assessment for land surface temperature analysis proposed can be utilized as an indication of developing water balance issues and drought. The analysis gives an understanding of the areas that impact water balance issues in the Drini I Bardhë basin and the future impacts of this on the region's wine agro-tourism by understanding the development of climate change in the region. Future research is required to understand seasonal temporal trends and their possible impacts on viticultural regions to understand how climate change can impact the vine development phases. There is also the appearance of an inverse correlation between emissivity and water balance at higher altitudes that would be undeniably driven by climate change and reducing the snowpack capacities placing the Drini i Bardhë Basin in precarious position for water resource.

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