International Journal of Science, Strategic Management and Technology
Volume **02** Issue **03** March-**2026** | ISSN: **3108-1762 (Online)** | Impact Factor: 3.8
An International, Peer-Reviewed, Open Access Scholarly Journal Indexed in recognized academic databases

# Evaluating the Nexus Between Altitude and Agricultural Productivity: A Case Study of Kashmir Valley

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**https://doi.org/**10.55041/ijsmt.v2i3.215

**Cite this Article**: Reshi, U. A. (2026). Evaluating the Nexus Between Altitude and Agricultural Productivity: A Case Study of Kashmir Valley. International Journal of Science, Strategic Management and Technology, *02*(03). https://doi.org/10.55041/ijsmt.v2i3.215



***Abstract***

Agriculture is the mainstay for the populace of Kashmir Valley and hence forms the backbone of its economy. With the diversification of agricultural crops towards the high-value cash crops of horticulture, it thus becomes imperative to study the relationship between the altitude and the productivity of Apple and rice in the Kashmir Himalayas. The current study is mostly based on secondary sources of data collected from some government and non-government agencies. In the course of this study, it has been discovered that the apple growing conditions in this region have consistently expanded to encompass lower altitudes and valley floors, which prove to be more favourable for paddy cultivation due to their geographical and agricultural conditions. Districts situated at higher altitudes such as Shopian and Kulgam exhibit the highest levels of productivity in apple cultivation, while simultaneously displaying the lowest levels of productivity in paddy cultivation. The majority of the farmers in the research area make their living from horticulture and paddy cultivation thus, there is a great deal of potential for analysing the regional changes in productivity with varying altitudes. The results were obtained by applying the correlation method to ascertain the district-wise differences in apple and paddy productivity, with varying elevations. According to the findings, there is a substantial positive association between apple productivity and altitude in high altitude districts and a large negative correlation between altitude and low altitude districts.

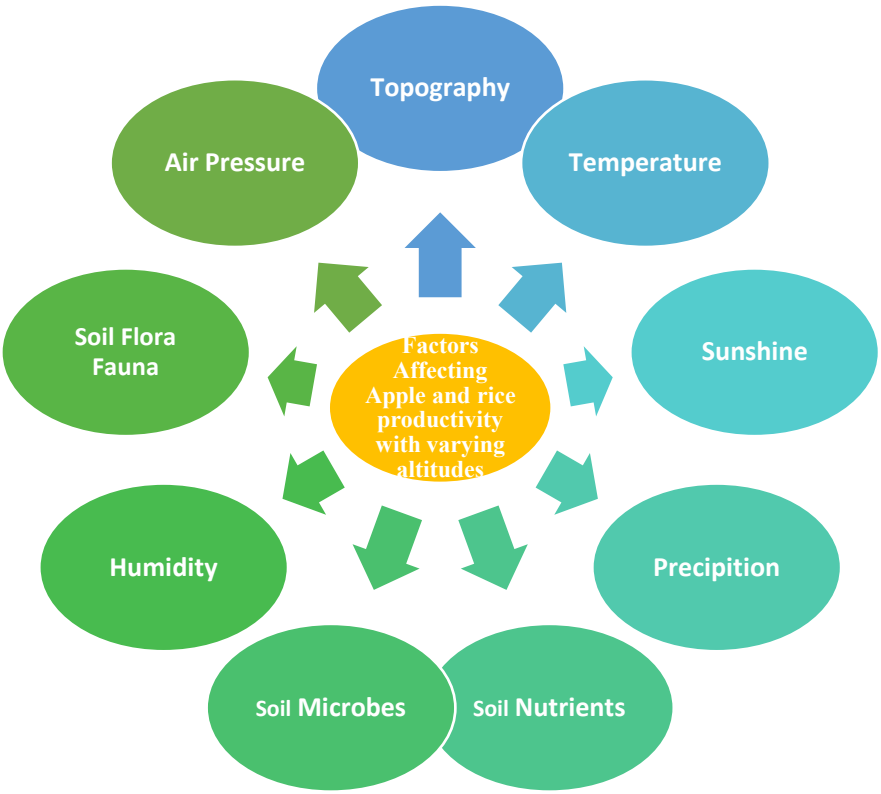
**Keywords:** Altitude, Productivity, J&K, Agro-climatic Suitability

## 1. Introduction

The economy of Jammu and Kashmir finds its primary foundation in agriculture, with a significant portion of its populace relying on this sector for sustenance. According to the Digest of Statistics 2020-21, approximately 70% of the population within the Union Territory is directly or indirectly associated with agricultural activities for their livelihood. This statistic underscores the paramount importance of agriculture in driving the economic dynamics of the region. From traditional crop cultivation to the cultivation of horticultural produce and engaging in livestock farming, agriculture serves as a linchpin in the socio-economic framework of the area. Its contribution not only sustains livelihoods but also plays a pivotal role in fostering overall prosperity and well-being in the region. Agricultural growth is critical for increasing farmer income and job possibilities. It is critical to implement methods targeted at improving and diversifying agricultural production. Horticulture is a vital source of livelihood and contributes significantly to the economy of Jammu and Kashmir. In the UT of Jammu & Kashmir, almost seven lakh families are directly or indirectly connected with the Horticulture Sector (Directorate of Horticulture, Kashmir). Jammu and Kashmir produces 75% of the total apples in the

country (Mir et al., 2022; Hanan, 2015). As the biggest apple grower in India, Jammu and Kashmir is producing more apples on a regular basis. It's also important to note that the apples are grown all around the valley. As conventional agricultural commodities are currently on the decline, horticulture is growing at the same time (Darzi, 2016). Horticulture's potential is enhanced by excellent agro-climatic conditions, making it a key export business in Jammu and Kashmir's UT. Apple, walnut, pear, almond, cherry, peach, apricot, plum, and other fruits are grown in Jammu and Kashmir's UT. The Kashmiri Apple is well-known for its flavour and looks. It is really in the outside market and generates a significant profit. Onion, tomato, potato, radish, mutter, turnip, carrot, green vegetables, and spices like chiles, garlic, and turmeric are among the principal vegetables farmed in the state. With the diversification of agricultural crops towards the high-value cash crops of horticulture. The farmers cultivate their land unintentionally. The low Altitude districts which are suitable for paddy are being practiced by horticultural crops like Apple which therefore shows the low productivity in Apple cultivation. Altitude plays an important role in the productivity of Apples and rice because due to the change in Altitude there is also the change in Argo-climatic factors (Figure 1) Such as Topography, Climate, Precipitation, Soil properties, etc. Scientists studying agriculture have demonstrated that every crop has a certain zero below which it cannot develop (Hussain, 2017). Districts situated at higher altitudes such as Shopian and Kulgam exhibit the highest levels of productivity in apple cultivation, while simultaneously displaying the lowest levels of productivity in paddy cultivation, The sustainability of the soil ecosystem and agricultural output in the high-altitude regions of the Himalaya are contingent upon abiotic and climatic conditions (Kumar, 2020). The productivity of agricultural production is predominantly linked to climatic circumstances (Priyanka, 2021). The productivity of Apple has experienced a decrease in the elevations reaching up to 1500 m above mean sea level (AMSL) amounting to approximately 40-50 per cent. This decline is attributed to the insufficiency of chilling requirement and the progression of flowering, both of which are consequences of the warmer climate observed during the winter season (Priyanka, 2021; Chadda and Sharma, 2009). Due to the climatic change the apple cultivation should be extended from low altitude to high altitude rather than from high altitude to low altitude what the Kashmiri Farmers are practicing. The traditional apple crop areas are shifting upward in Himachal Pradesh as a result less suitable areas transforming into unsuitable and severely cold areas which were earlier not suitable are becoming suitable for apple cultivation (Jyoti et al., 2017). Now the traditional Apple orchards in the bottom valley require more pesticides, fungicides, and fertilizers which decreases the output cost. The massive land transformation is largely driven by anthropogenic actions and has been mostly adverse in nature, giving rise to multiple environmental issues in the ecologically sensitive Kashmir valley (Alam et al., 2020); Kashmir valley witnessed drastic land use and land cover changes mainly as a result of an increase in population size, economic growth, changes in agriculture practices, and execution of different development projects, particularly during last three decades (Ahamed et al., 2022). However, the LULC changes are not being monitored in a systematic way and estimation of the magnitude of the changes is rarely being done. The Low altitude land which is flat and has a higher temperature than the high altitude is more suitable for paddy cultivation but the farmers have changed the traditional system of cultivation by starting cultivation of cash crops. They have started transforming their irrigated land from crop cultivation to fruit cultivation and transplanting of apple trees on their irrigated land (Lone et al., 2019). The Altitude Horticulture sector has brought more land under orchards. The area under horticulture has been high during the past three decades i.e. 1980, 1990, 2000. About 4.5 lakh families are engaged directly or indirectly with horticulture activities (Khursheed and Taufique, 2019). Naseer et al. (2013) revealed that the decrease in the growth rates of agricultural outputs, most of the shift it to horticulture (Lone et al., 2019). The farmers have changed the old age system of cultivation by starting cultivating of cash crops. They have started transforming their land from crop cultivation to fruit cultivation like transplanting of apple trees on their irrigated land since 1980 in the state especially in the valley of Kashmir (Malik et al., 2012). Orchards have shifted to 2500-1500 meters in the 2000s compared to the cultivated elevation of 2500– 2000 meters during 1980s. While the changing climate is lowering apple output in the state's low altitudinal zones, it is opening up new chances for apple cultivation in higher altitudes, where conditions are becoming more favourable for apple growing. Though previous studies have suggested the climate change to be a factor in the altitudinal shifting of apple orchards. A study on different regions of China has made it clear that change in temperature leads to the deterioration of the quality of apple crop.

**Fig.1: Factors Affecting Apple and Rice Productivity with Varying Altitudes**




## 2. Study Area

The Kashmir Himalayas, which are located in the northwest of the Himalayas between 32° 22′ and 34° 43′ N latitude and 73° 52′ and 75° 42′ E longitude (Shafiq et al. 2018c), are the subject of this study. The valley is shaped like an oval bowl and is bordered by the Greater Himalayas from the north-northeast and the Middle Himalayan (Pir-panjal) ranges from the south-southwest (Fig. 1) The Jhelum River, which is regarded as the Kashmir Valley's lifeline, flows across the whole region. It covers an area of about 16,000 square kilometres and has an elevation range of 1060 to 6000 meters above sea level. The physiography spans from the valley floor to the highest alpine regions. The valley has a unique regional climate due to its considerable altitude fluctuation (1450–5500 masl) and enclosure by mountain ranges. In winter, temperatures can drop as low as -9 °C, while in summer, they can reach 38 °C. The Kashmir Valley has average mean maximum and lowest temperatures of 19.27 °C and 7.29 °C, respectively, along with an average annual rainfall of 84 cm. Due to the Indian winter monsoon, the study area receives the majority of its precipitation during the winter from western disturbances embedded in large-scale subtropical westerlies (Dimri et al., 2016; Shafiq et al., 2018; Rees and Collins 2006). The greatest amount of snowmelt runoff happens in the summer, resulting in the least amount of area covered in snow.

The main economic activities in the valley are agriculture and horticulture, both of which rely on the availability of water supplies.

**Fig.2:StudyAreaMap**

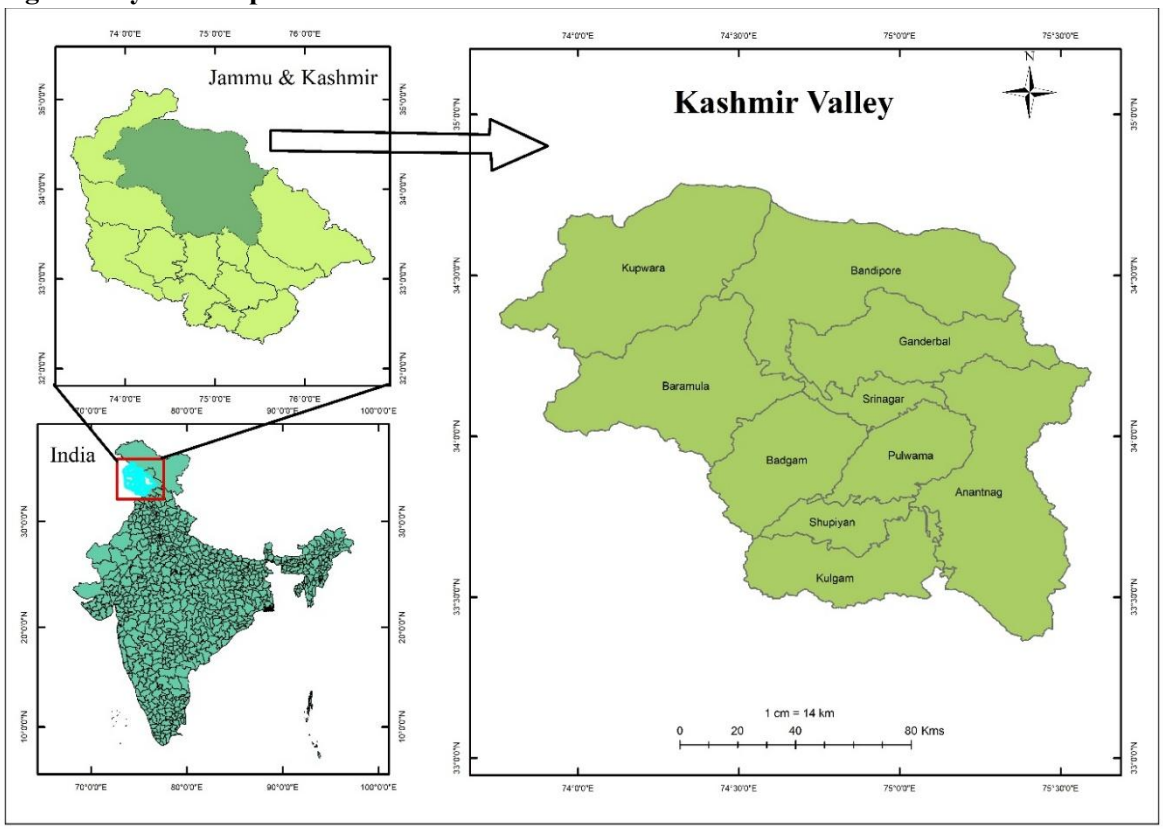



**Fig 2. Location of Kashmir Valley**

**Elevation of Kashmir valley**

The Digital Elevation Model (DEM) of the Kashmir Valley plays a crucial role in advancing horticultural research and development in the region. By providing a detailed three-dimensional representation of the terrain, DEM data aids in understanding the topographic variations that significantly influence microclimates, soil characteristics, and water flow patterns. This information is invaluable for optimizing land use, selecting suitable crop varieties, and designing efficient irrigation systems tailored to the diverse landscapes within the valley. Moreover, DEM analysis enables researchers to identify optimal sites for orchards, vineyards, and other horticultural ventures, maximizing productivity while minimizing environmental impact. As such, integrating DEM technology into horticultural research not only enhances agricultural practices but also contributes to sustainable land management strategies in the Kashmir Valley.

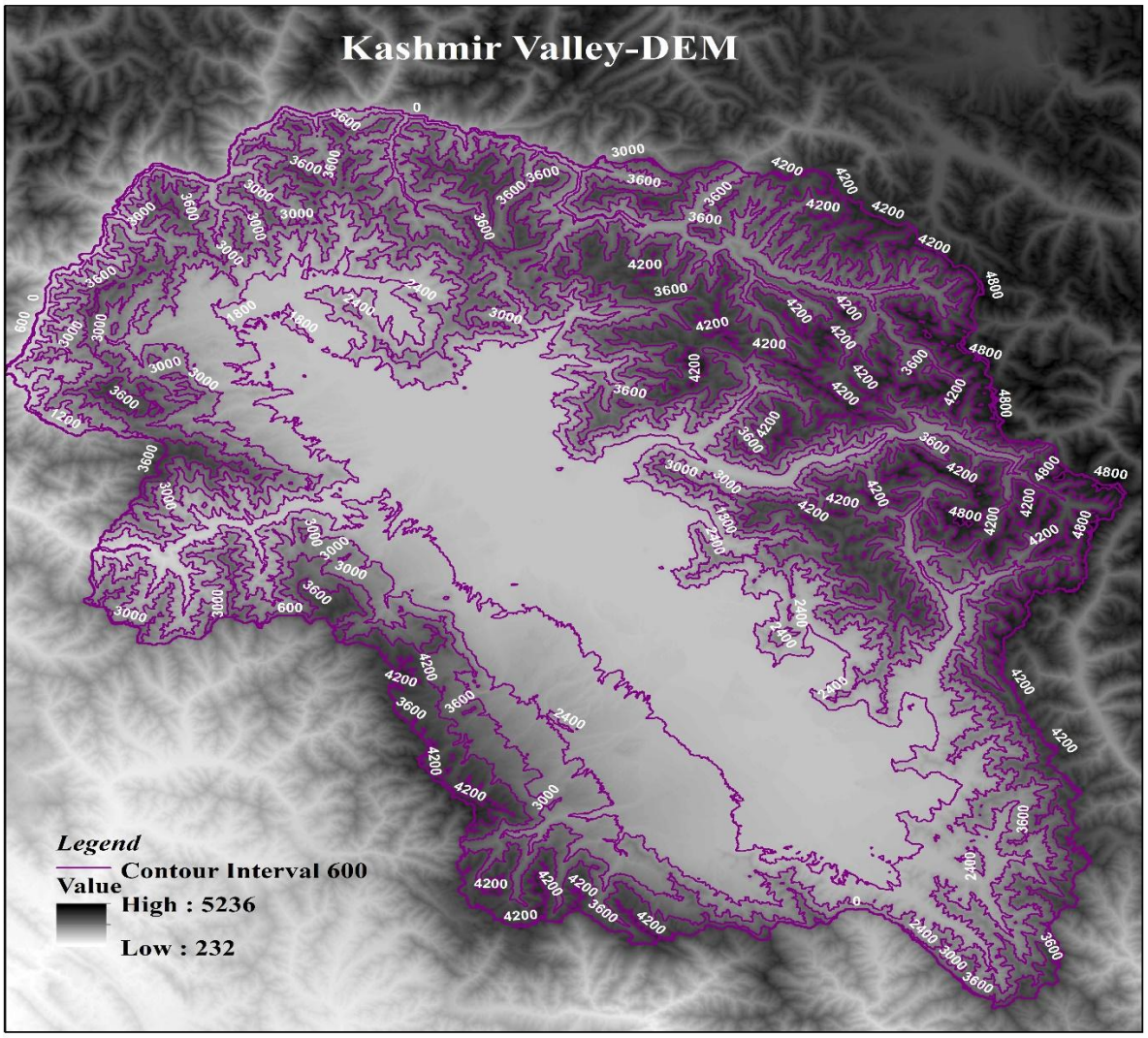



**Fig. 3** Elevation of Kashmir Valley.

## Literature Review

Apple cultivation is reliant on the surrounding agroclimatic conditions, which influence the quantity and quality of apples produced (Khatri et al., 2021). The Kashmir Valley is known for its fruit and flower production, with apple growing providing a significant portion of the local population's income (Rather et al., 2013). The state has favourable weather conditions and fertile soil, making it ideal for growing temperate fruits (Sharma et al., 2012). The maximum portion of the study region is under Apples followed by rice (Sultana et al., 2021). Geographic elevation significantly impacted flowering, fruit weight, moisture, and TSS concentration (Narayal et al., 2020). Increasing altitude may impact fresh apple quality and, consequently, how consumers perceive its sensory qualities and accept it (Cantin et al., 2022). High-altitude apple cultivation is becoming more feasible, but low-altitude apple production is being negatively impacted by climate change (Cantin et al., 2022). Numerous investigations have exhibited the impact of altitude on the physiological processes involved in fruit development, ripening phase, chemical makeup, and sensory attributes (Iglesias et al., 2018; Charles et al., 2018; Fadanelli, et al., 2004; Aslantaş et al., 2007). However, places appropriate for apple production exhibit input-output imbalances due to regional disparities in resource endowments, geographical position, economic basis, technical progress, agricultural infrastructure, and government behaviour and policies (Wang et al., 2023; Souza et al., 2023). Similarly, the areas deemed most suited for rice production were those with flat surfaces, lower slopes, and medium slopes, respectively, because they promote uniform water distribution, effective surface drainage, and reduced erosion exposure (Yangouliba et al., 2020; Samanta et al., 2021). Numerous research shown that slopes that are ideal for growing

rice often have less than 3% slope (Gumma et al., 2009; Danvi et al., 2016; Mandal et al., 2010). Areas with slopes of less than 1% are deemed most suitable, those with slopes of 1% to 3% are suitable, while slopes greater than 3% are unsuitable (Yangouliba et al., 2020).

## 3. Database And Methodology

This study relies secondary data sources for its analysis. Specifically, data regarding the cultivation of apples and rice were sourced from the Digest of Statistics 2021-22 published by the Jammu & Kashmir Government. The variables under scrutiny in this study include altitude and productivity. To assess the productivity of apples and rice at the district level within the study region, a key metric was computed: production per unit area. This metric, expressed as productivity, was calculated by dividing the total production by the total area cultivated. The formula used for this computation is as follows:

$$Productivity = \frac{\text{Total Production}}{\text{Total Area}}$$

This calculation allowed for a granular examination of agricultural productivity, providing insights into the efficiency of land utilization in apple and rice cultivation across different districts. By focusing on production per unit area, the study aims to discern patterns and variations in productivity levels, shedding light on the interplay between altitude, land use, and crop yields. Additionally, employing district-level data offers a localized perspective, enabling researchers to identify regional disparities and potential factors influencing agricultural output. Through this methodological approach, the study aims to contribute valuable insights to the understanding of agricultural dynamics in the study region, informing policy-making and agricultural planning initiatives aimed at enhancing productivity and sustainability.

## 4. Results and discussion

The relationship between agricultural productivity and altitude is intricate and varies significantly depending on the crop being cultivated. When considering apples, higher altitudes often coincide with cooler temperatures, providing optimal conditions for bud development and fruiting. Additionally, improved air circulation at altitude reduces disease pressure, enhancing overall tree health and productivity. Well-drained soils characteristic of mountainous regions also benefits apple cultivation by preventing waterlogging and root rot. Furthermore, microclimate variability allows farmers to select optimal microsites for orchards, maximizing growing conditions and ultimately leading to higher apple productivity. Conversely, rice cultivation at higher altitudes faces numerous challenges. Limited water availability due to lower precipitation and increased evaporation rates can lead to water stress during critical growth stages, reducing yield potential. Additionally, shorter growing seasons and rugged terrain hinder effective water management and limit the suitability of terraced paddies, further constraining rice productivity. Moreover, varietal adaptation plays a crucial role, as rice varieties selected for lowland cultivation may not perform optimally at higher altitudes, exacerbating productivity limitations. Understanding these dynamics is essential for developing tailored agricultural strategies to optimize productivity across different altitudinal zones. However, in our case we have mainly studied the relationship between altitude and productivity in case of Kashmir valley. For doing so we have utilised the correlation technique. The correlation matrix examining altitude reveals a several of noteworthy relationships (Table 1). In particular, there are discernible patterns between altitude and agricultural productivity across the J&K. Notably, altitude exhibits a positive and significant correlation with apple productivity. This suggests that as altitude increases in this region, so does the productivity of apple crops. The positive correlation between apple productivity and altitude in a region like J&K can be attributed to several factors. First, altitude often corresponds to cooler temperatures, which can be advantageous for certain crops like apples that thrive in cooler climates. Cooler temperatures can extend the dormancy period of apple trees during winter, promoting better fruit bud development and overall tree health, thus leading to higher productivity. Additionally, higher altitudes may offer better air circulation and drainage, which can reduce the risk of diseases and pests that commonly affect apple trees. Furthermore, mountainous regions often have well-drained soils with good water retention properties, which are favourable for apple cultivation. These factors collectively contribute to the positive correlation observed between apple productivity and altitude.

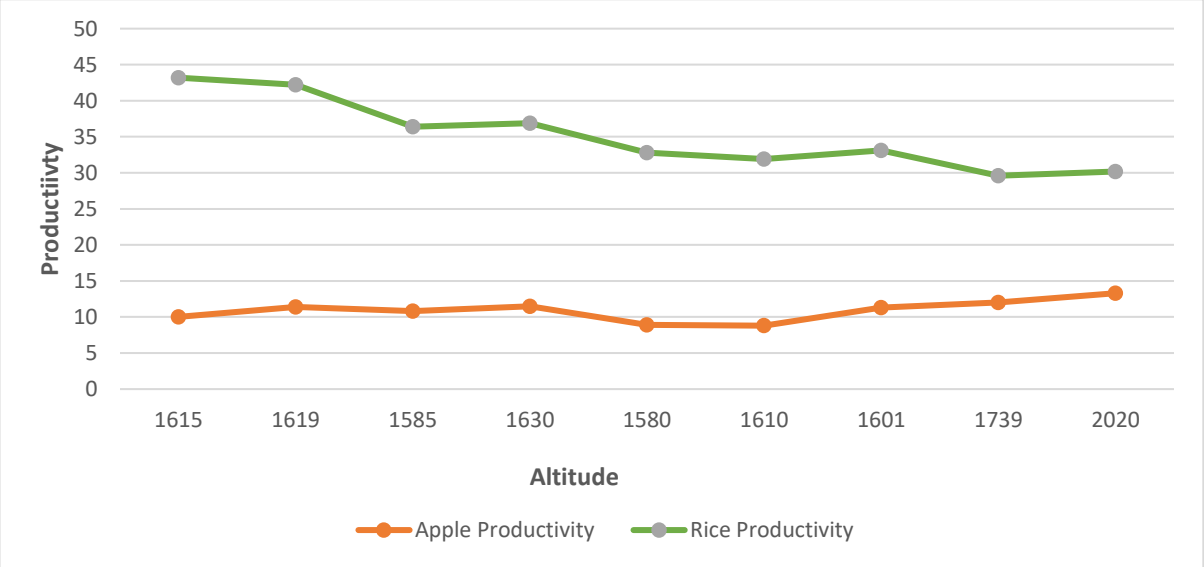
**Table 1: correlation matrix**

| Variables | Mean | Std. Dev. | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|---|---|
| (1) **Avg. Altitude** | 1666.556 | 140.564 | 1.000 | | | | |
| (2) **Avg. Rainfall (mm)** | 54.411 | 16.193 | -0.578 | 1.000 | | | |
| (3) **Apple productivity** | 10.889 | 1.456 | 0.734* | -0.500 | 1.000 | | |
| (4) **Rice productivity** | 24.256 | 5.383 | -0.619** | -0.106 | -0.431 | 1.000 | |
| (5) **Labor** | 468866.6 | 251706.57 | -0.553 | 0.574 | -0.614** | -0.132 | 1.000 |

* $p<0.05$.
**
$p<0.10$.

Conversely, a contrasting negative relationship emerges between altitude and rice productivity. This indicates that as the average altitude rises, the productivity of rice diminishes. Also, the negative correlation between rice productivity and altitude is primarily due to the crop's specific requirements and limitations. Rice is a water-intensive crop, heavily reliant on consistent water availability throughout its growth cycle. At higher altitudes, water availability may be limited due to factors such as lower precipitation levels, reduced water retention in soils, and increased evaporation rates. Additionally, colder temperatures at higher altitudes can result in shorter growing seasons, which may not align with the longer duration required for rice cultivation. Moreover, rice cultivation often requires flat or gently sloping terrain for effective water management through irrigation systems, which may be challenging to achieve in mountainous regions. These constraints collectively lead to reduced rice productivity with increasing altitude, as evidenced by the negative correlation observed. Also, the above observed correlations are evident from the from *Figure 3*.

**Figure 4: Productivity growth with altitude: Rice and Apple**




Furthermore, the correlation matrix further elucidates a negative correlation between average rainfall and agricultural productivity, with a more pronounced impact on apple productivity compared to rice. This discrepancy can be attributed to the divergent water requirements of these crops, where rice necessitates more irrigation or water compared to apple cultivation. These observations align with the overarching principle that the concentration of basic cations tends to increase with rising altitude, thereby influencing agricultural productivity across different crops and regions. This

relationship underscores the complex interplay between geographical factors, climatic conditions, and agricultural outcomes, underscoring the need for nuanced strategies in agricultural management and planning.

## 5. Conclusion

The economic landscape of Kashmir valley is heavily reliant on agriculture and horticulture, with a significant portion of the population engaged in these sectors. While traditional agricultural commodities are on the decline, horticulture, particularly apple cultivation, is gaining momentum. However, shifting climatic patterns are reshaping agricultural dynamics, prompting farmers to adapt their practices. The study explores the intricate relationship between altitude and crop productivity, revealing contrasting patterns for apples and rice. Higher altitudes favour apple cultivation due to cooler temperatures and favourable soil conditions, leading to higher productivity. In contrast, rice productivity diminishes with increasing altitude, attributed to water availability constraints and terrain suitability issues. Furthermore, the correlation between average rainfall and agricultural productivity underscores the diverse water requirements of different crops, highlighting the need for nuanced strategies in agricultural management. These findings emphasise the importance of understanding geographical and climatic factors in optimising agricultural productivity and sustainability, informing policy-making and planning initiatives in the region.

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