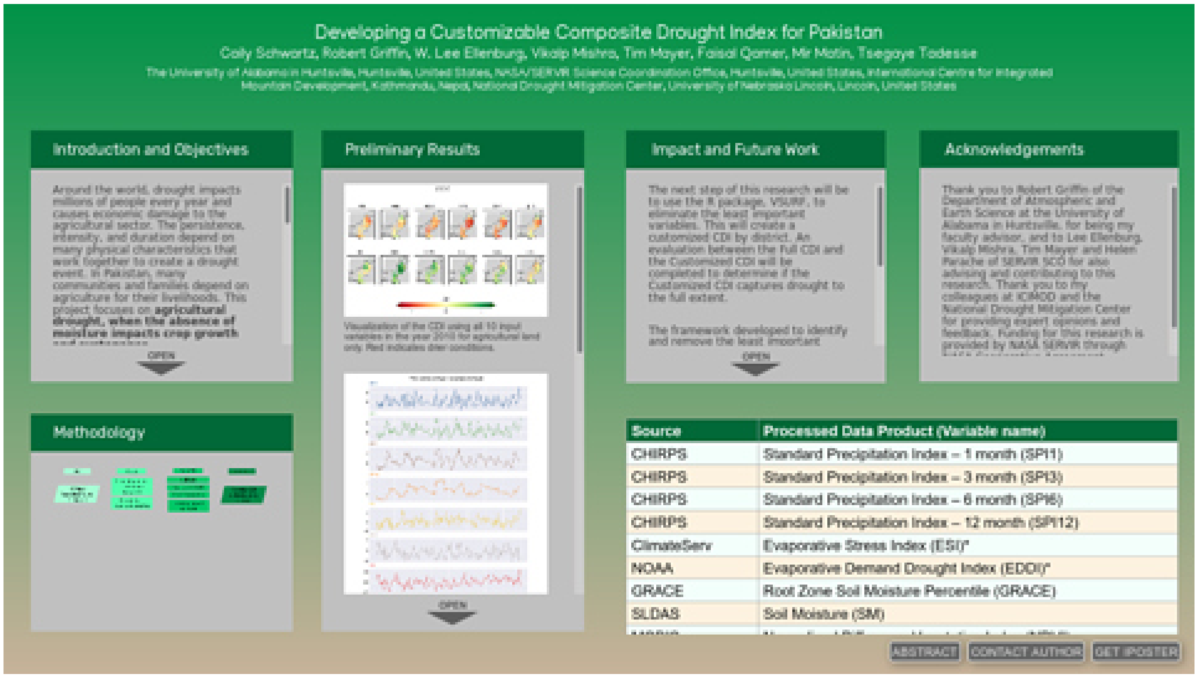
Developing a Customizable Composite Drought Index for Pakistan



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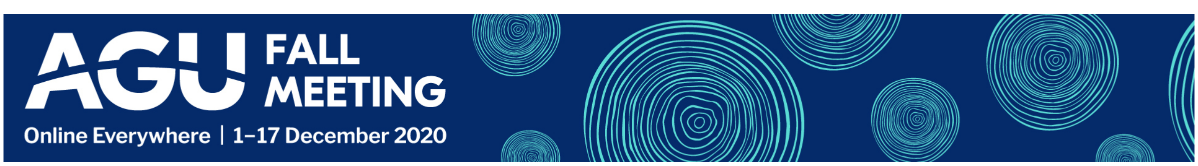


INTRODUCTION AND OBJECTIVES

Around the world, drought impacts millions of people every year and causes economic damage across multiple sectors. The agricultural sector is threatened by future droughts, creating a need to understand the propagation of drought in these areas [1]. Originating from a lack of precipitation, the extent, intensity and duration of a drought event are determined by a variety of factors [2]. This study examines geophysical variables that make up multiple aspects of the hydrological cycle in order to capture the full extent of agricultural drought [3]. In Pakistan, many communities and families depend on agriculture for their livelihoods. This study focuses on agricultural drought, when the absence of moisture impacts crop growth and sustenance.

Figure 1: Study area, Pakistan

This study aims to **identify historical agricultural droughts** between 2004-2019 using 10 geophysical variables and **determine what variables have little importance in this identification**. Satellite data products or model outputs are used for all input variables. Understanding the interactions between the data will provide information on temporal and spatial patterns of how drought is presented in irrigated and rainfed areas. This knowledge will assist in creating a Customized Composite Drought Index in future work.

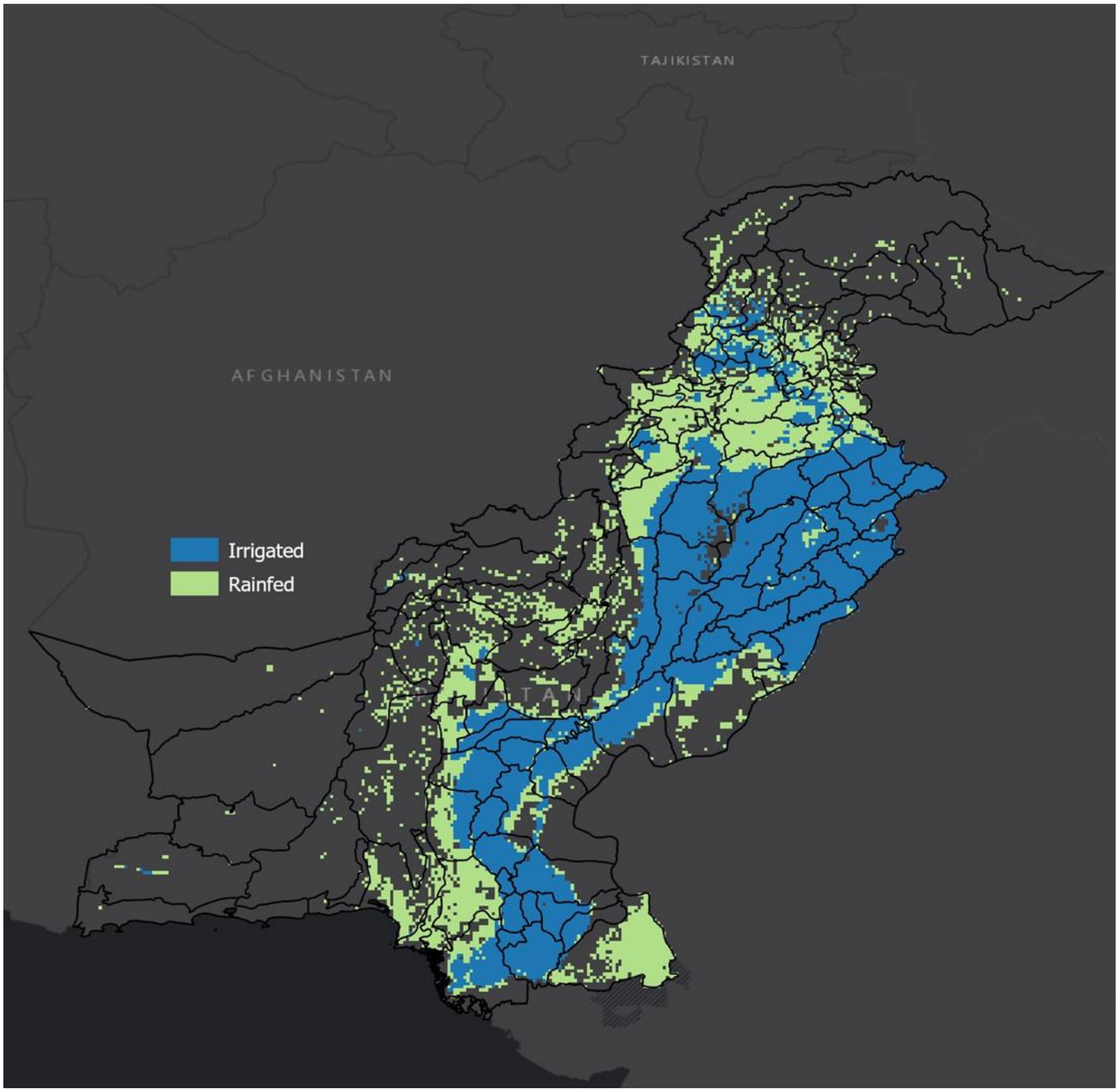
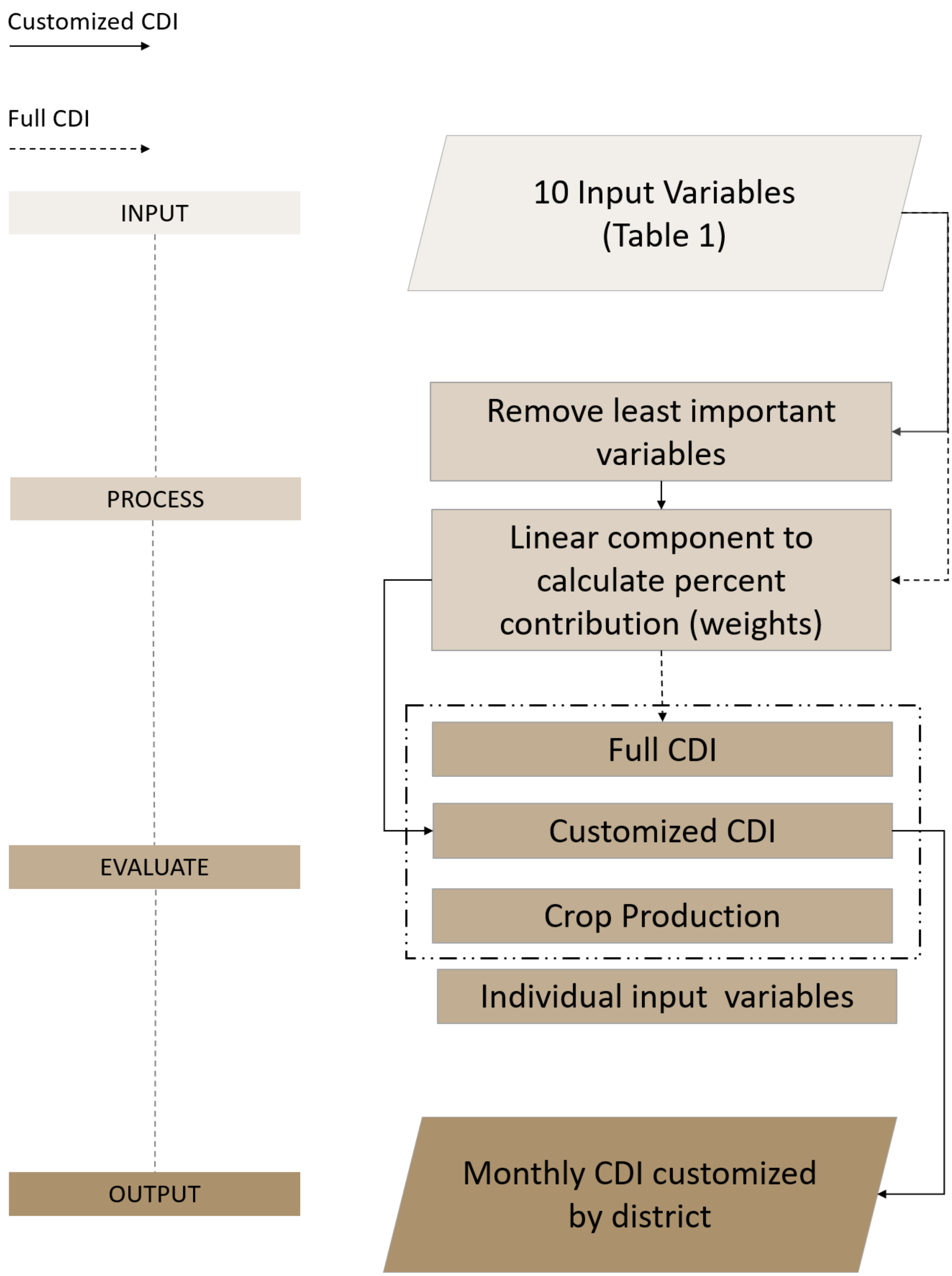


Figure 2: Areas of irrigated and rainfed agriculture by district in Pakistan.

METHODOLOGY



This study will result in two CDIs, the Full CDI, containing all 10 input variables (Table 1) and the Customized CDI, containing a subset of the variables by month and by district.

Each input dataset is processed to have a temporal resolution of 1 month and spatial resolution of 5km and is standardized using the z-score. To create the Customized CDI, variables will be removed after preprocessing. The Full CDI will skip this step. Both CDIs will use the eigenvectors of the first linear component to calculate weights for each input variable. This allows for each input to have a different amount of influence in determining drought based on month and location (Fig. 5). These weights are then multiplied by the identified standardized datasets to create the Customized CDI or multiplied by all standardized input datasets to create the Full CDI (Fig.3). The Full CDI and Customized CDI will be evaluated with crop production data to identify how drought is presented in different districts.

Source	Processed Data Product (Variable name)
CHIRPS	Standard Precipitation Index – 1 month (SPI1)
CHIRPS	Standard Precipitation Index – 3 month (SPI3)
CHIRPS	Standard Precipitation Index – 6 month (SPI6)
CHIRPS	Standard Precipitation Index – 12 month (SPI12)
ClimateServ	Evaporative Stress Index (ESI)*
NOAA	Evaporative Demand Drought Index (EDDI)*
GRACE	Root Zone Soil Moisture Percentile (GRACE)
SLDAS	Soil Moisture (SM)
MODIS	Normalized Difference Vegetation Index (NDVI)
SLDAS	Vapor Pressure Deficit (VPD)*

* Indicates model output

Table 1: Input variables

Pakistan identifies wheat, maize, rice, cotton and sugarcane as the most important crops. For this analysis, we will use the production data from wheat, maize, rice, cotton and barley to evaluate both CDIs. **Crop production would be expected to decrease in the presence of drought conditions.** The months of the growing season for each crop will be identified (Table 2) and used to evaluate the CDIs.

PRELIMINARY RESULTS

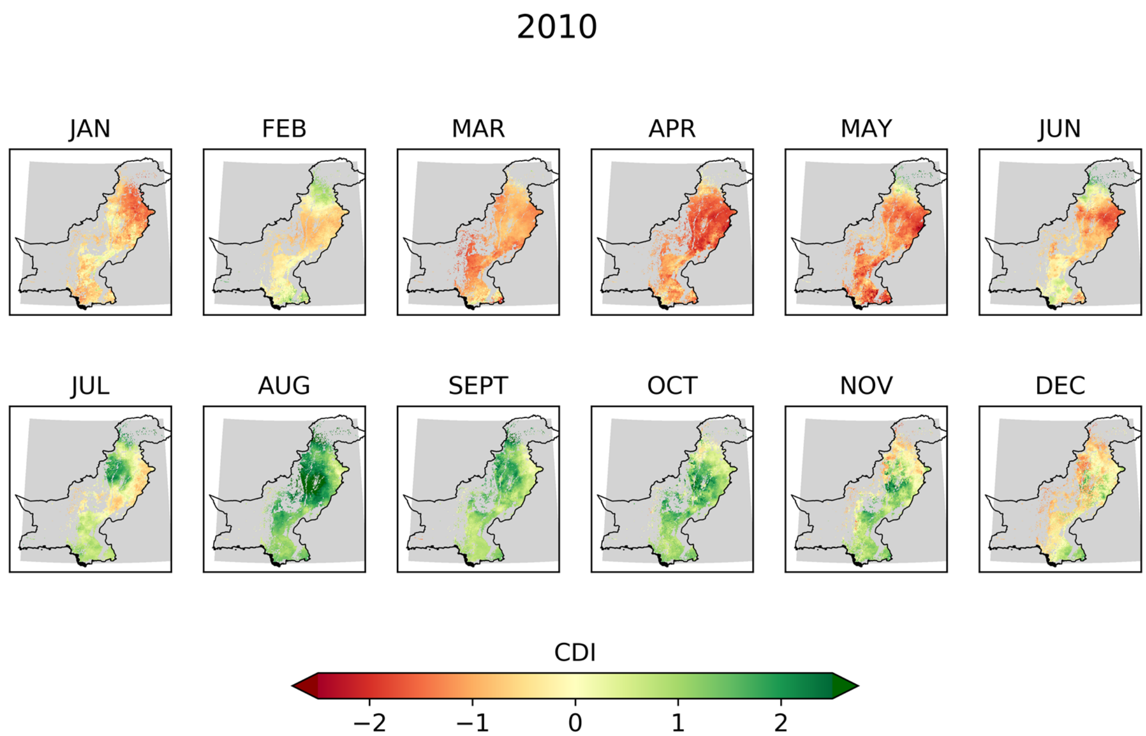


Figure 3: Visualization of the CDI using all 10 input variables in the year 2010 for agricultural land only. Red indicates drier conditions.

The CDI has a temporal resolution of monthly and a spatial resolution of 5km. The Full CDI uses all 10 input variables. These variables account for different aspects of the hydological cycle. This will provide the full extent, intensity and persistance of a drought event.

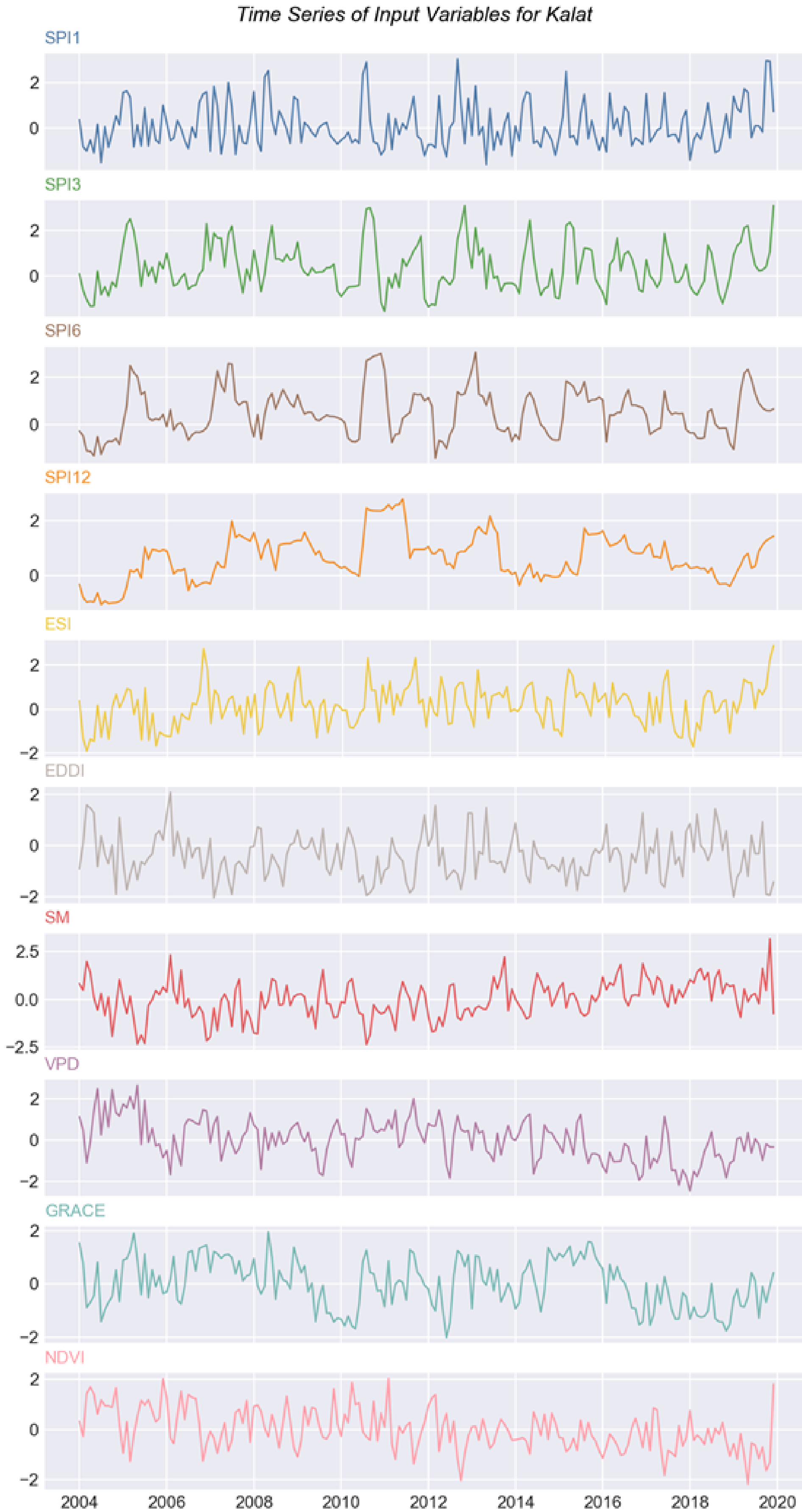


Figure 4: Time series for all 10 input variables over the study period (2004-2019) for the district Kalat.

By evaluating the individual datasets, there will be a comprehensive look into how the variables have changed during the study period. Another outcome of evaluating the datasets individually, will be a better understanding of how each of these inputs contribute to agricultural drought and if there are any spatial or temporal patterns present. This evaluation will also distinguish between irrigated and rainfed areas, as seen in Figure 2. The green areas represent rainfed agriculture and blue areas represent irrigated agriculture. Drought will show up differently in these two areas, determined by the source and availability of water.

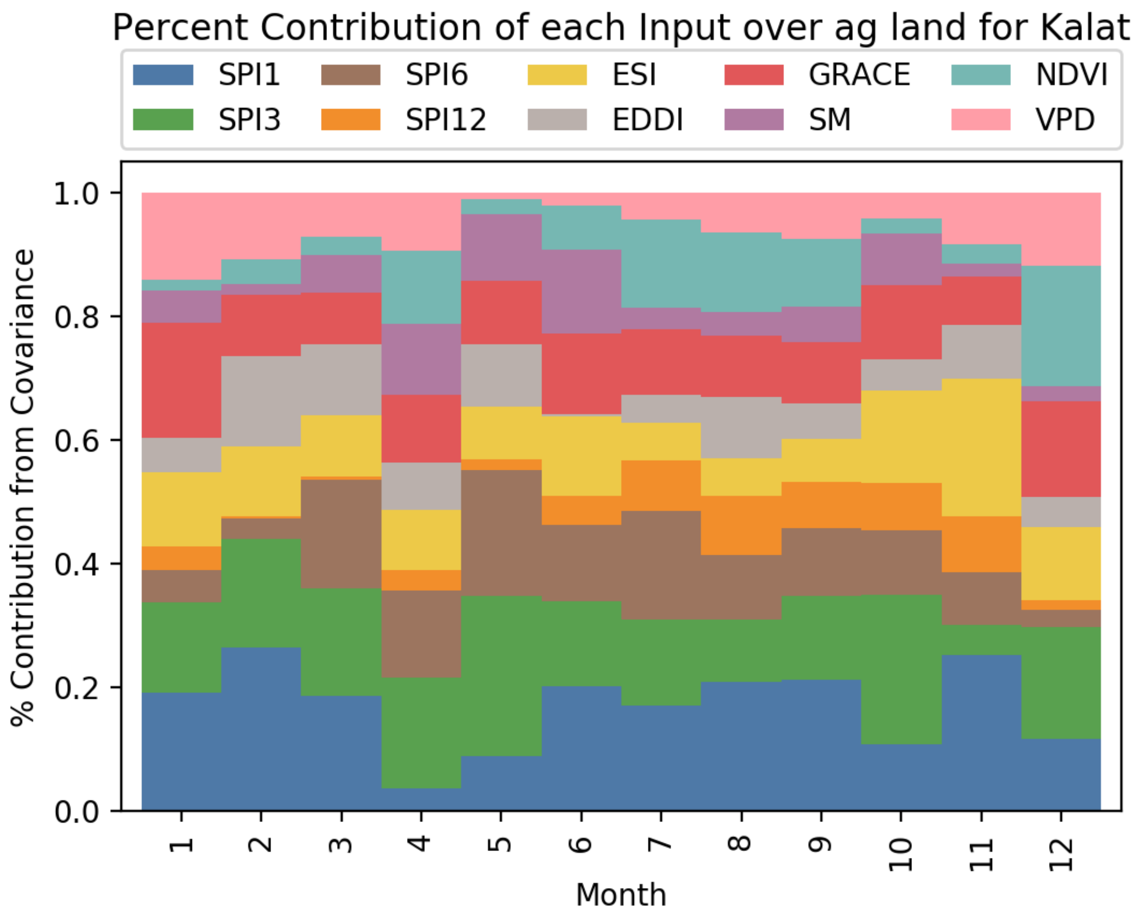


Figure 5: Percent contribution of each input variable in each month for the district Kalat.

Each input has a different amount of influence in determining drought based on month and location. These weights are then multiplied by the standardized datasets to create the full CDI and the full CDI is standardized using the z-score

FUTURE WORK

Future work for this project includes creating the customized CDI by removing variables, based on importance, using VSURF, a package in R that uses random forest to select variables. This step will remove the variables that contribute the least when identifying drought in each district.

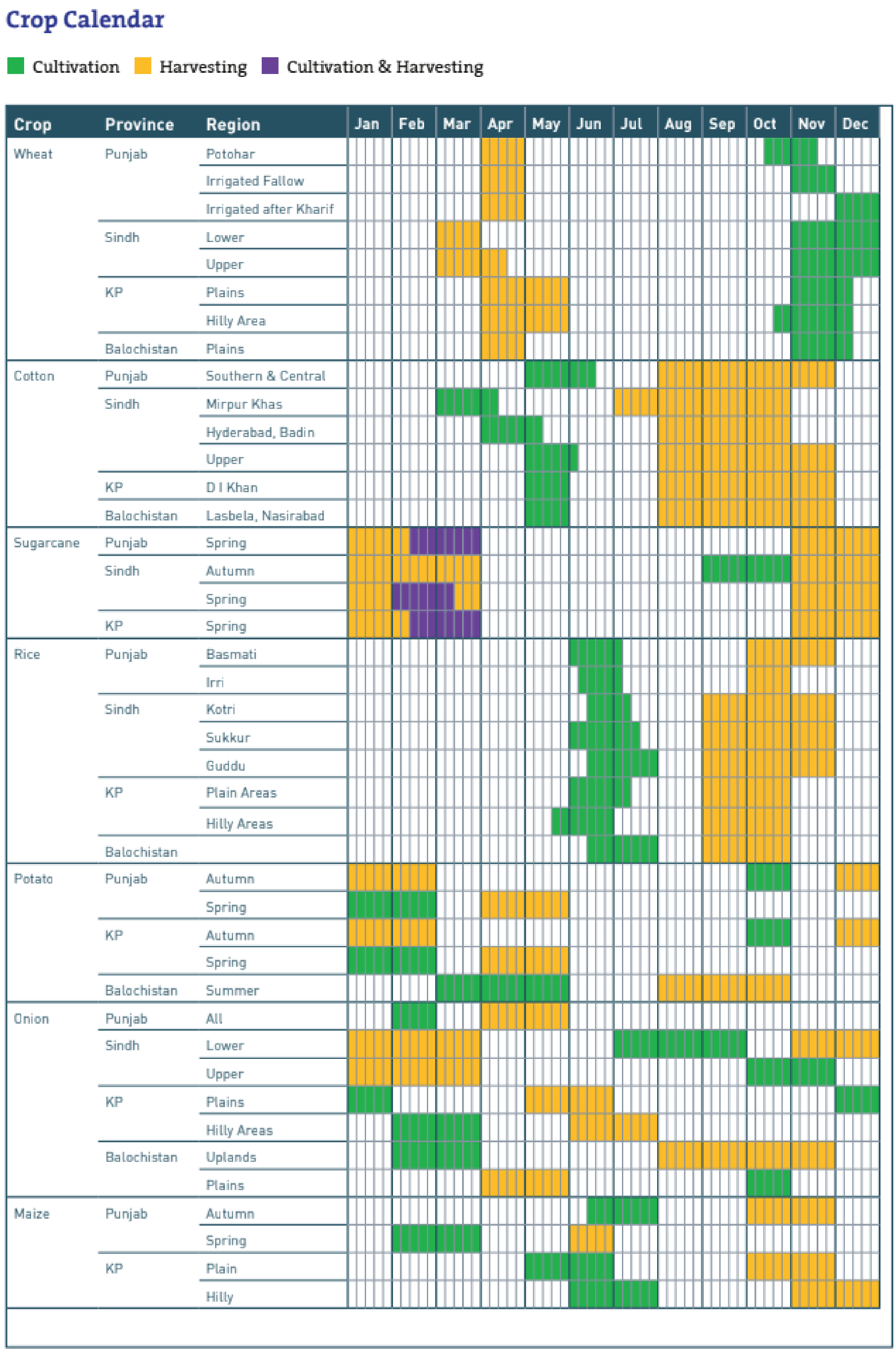


Table 2: Table showing when crops are cultivated and harvested in Pakistan by province.

These results, the customized CDI, will be evaluated with crop production, as done with the Full CDI and then will be compared to each other. This step will determine whether the customized CDI, with less variables, still recognizes drought in a similar way to the Full CDI. The end result will be to identify the least amount of geophysical variables, in each district, that identify drought to the full extent. The framework developed in this study will be able to be used to enhance existing drought monitoring and forecasting systems in the region.

IMPACT AND ACKNOWLEDGEMENTS

The framework developed to identify and remove the least important variables by location will allow for the **enhancement of existing drought monitoring and forecasting systems in the region**. A customized drought index will use only the most influential variables while still identifying the onset, persistence and intensity of drought to the full extent.

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ABSTRACT

Pakistan has experienced intense agricultural droughts in recent years, with the southern provinces experiencing the most severe drought conditions. These prolonged dry conditions often result in failed crop production, impacting families and communities. To reduce the impacts a drought may have on a community by identifying dry conditions, drought indices are used. A customizable composite drought index (CDI) is developed to improve the spatial and temporal understanding of historical agricultural droughts that have affected Pakistan. An in depth analysis using 9 input variables will provide information regarding the most important variables for differing locations. This framework can enhance drought monitoring and forecasting systems. The performance of the CDI will be evaluated by using production data from different crops that have significant economic value in Pakistan. These crops include wheat, rice, maize, cotton and barley. The expected relationship between the CDI and crop production would be to see production decrease when the CDI decreases, an indication that crops failed due to drought. The CDI is made more precise by evaluating only agricultural areas using the months of the growing season for each specific crop. This will allow for a custom drought index to be developed based on crop type and geographic location that only uses the most important variables, while still capturing the full extent of historical drought.

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