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Assessment of growing water and food security crises in Afghanistan

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Abstract

The gap between Afghanistan's international engagements and the development and management of its national water resources become increasingly pronounced in terms of regional peace and security. Therefore, it is important to understand what would happen if Afghanistan was unable to use its water resources and became cut off from the world. Afghanistan's chances for peace and stability will be limited if food insecurity, water scarcity, and overpopulation persist. Here, the water resources could become the main cause of social unrest, instability, mass migration, and rising conflict among the riparian nations connected by economic, historical, cultural, and environmental ties if they are not improved and managed responsibly. Moreover, the prolonged crisis can make it more difficult for Afghanistan to address issues with food and water insecurity as been in the past. Additionally, the already shaky government structure of the nation further strains by natural disasters. Therefore, the food and water problems in Afghanistan must be taken into account, as well as their effects on local instability and security. Therefore, this study examines the possibilities for water resources in Afghanistan as well as the emergence of droughts. As a result, the final status of the country's food and water security was assessed.

Keywords: Transboundary basin, regional water security, hydropolitics, peace, stability, food security, wheat, data analysis

1. Introduction

The country's possible economic collapse and a humanitarian catastrophe are imminent in Afghanistan. Moreover, the deteriorating environmental circumstances brought on by the continuing consequences of climate change make the situation worse. Therefore, the events that are taking place demand attention, and there is a need to provide some reflections and critical insights on the socio-economic and political risks that arise when characterizing the scope of the refugee crisis and the impacts of climate change as a catalyst on the underlying conflict divisions (Rajmil and others, 2022).

Although Afghanistan has many water resources, and its geography provides significant opportunities for their exploitation (King ve Sturtewagen, 2010), it is an unfortunate nation that cannot utilize its water resources (STIMSON, 2011; Ahmadzai ve McKinna, 2018). The Amu Darya, the ancient Oxus (which runs 1,100 kilometres through Afghanistan and borders Central Asia), the Helmand (1,300 kilometres), the Harirud (650 kilometres through Afghanistan), and the Kabul River are the four main river networks (460 kilometres). Only the Kabul River, which Pakistan's Indus River Basin joins, reaches the ocean. Many streams and rivers drain into the nation's desert regions, depleting themselves via evaporation without refilling the four main networks. Other rivers and streams only flow occasionally. (Blood, 2001). Despite these numerous rivers, river basins, lakes, and desert regions, thirty years of war have damaged the current water infrastructure. This lack of water management capability exacts a great price, worsening food shortages, unemployment, water disputes, and the growth of crops that can rival the production of illegal substances. In addition, existing infrastructure is vulnerable to disastrous seasonal floods and droughts without the ability to retain and redirect water (STIMSON, 2011).

Moreover, almost all of Afghanistan's major rivers flow into neighbouring riparian states due to the country's landlocked natural location. As a result, Afghanistan's borders are experiencing increased transboundary worries (Yıldız, 2017). Afghanistan also has a low electrification rate of only around 30–38%. In addition, the transboundary water management issue remains a crucial obstacle to hydropower potential utilization (Ahmadzai ve McKinna, 2018).

Many people in Afghanistan reside in rural areas, where agriculture and livestock are the country's main economic drivers (Ahmadi and others, 2022). However, the nation is having many difficulties marketing its crops. Some of these obstacles include a lack of local infrastructure, poor market awareness, an absence of industries that utilize crops, a lack of facilities for proper storage, a low on-farm commodity price, the dispersion of yields, and a deficiency of highways for transportation (Khairi and others, 2022). According to Kenyon's report (2021), approximately 80% of Afghans are employed in agriculture in some capacity. In addition, the United Nations estimates that 7 million Afghans are experiencing issues connected to the second drought in four years (Kenyon, 2021).

Three main concerns, including the withdrawal of the USA and its allies, the Taliban seizing power, and the current humanitarian and economic catastrophe, made Afghanistan the focus of media attention in the previous year (2021) (Barlas, 2022). At the global and regional levels, there are significant security worries following the Taliban takeover of Afghanistan on August 15, 2021 (Herd, 2021; Barlas, 2022). The bordering nations worry that Afghan land might be used against them strategically. Despite constructing most of the Durand Line border, Pakistan, which has the longest border with Afghanistan, is worried about potential attacks by the Tehrik-i-Taliban Pakistan (TTP) in the former tribal areas (Khan, 2022), for example. Following the Taliban's seizure of Kabul, tens of thousands of people flocked to Hamed Karzai International Airport as fear and terror increased. According to authoritative sources, international forces helped to evacuate around 124,000 Afghans from Kabul between the middle and end of August 2021. Additionally, nearly 600,000 people relocated to Pakistan and Iran (Barlas, 2022).

In addition to these concerns, the people are apprehensive that the Taliban face various difficulties, including acute food crises, just as the issues with peace and stability (Khan, 2022). The fact that this situation is accompanied by drought puts Afghanistan's agriculture in great difficulty. According to IFRC (2022), the area sown with winter wheat is much below average due to the prolonged drought. According to field reports, near the conclusion of the planting window in December, half of the land typically planted with wheat was fallow. According to the United Nations, hunger is also getting worse in Afghanistan, where 95% of people lack enough to eat nearly every day. Again, for IFRC (2022), La Nina is anticipated to deliver drier-than-average weather in the upcoming months, extending the extreme drought into a second year and making the few crops that were sown vulnerable to harsh conditions.

In Afghanistan, it is essential to assess the chronological development to comprehend the escalating problems in food and water issues. In this context, this study includes research on Afghanistan's key crops, water potential, and the development of droughts. As a result, the nation's food and water security topic was evaluated.

2. Afghanistan: Water Potential

Afghanistan's primary surface water resources are the Amu Darya, the Helmand River, the Kabul River, and the Harirud and Murghab rivers. Afghanistan shares these rivers with Iran, Pakistan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan (Ahmadzai and McKinna, 2018). In Figure 1, Afghanistan's domestic and transboundary basins were given via ArcGIS pro v2.19's layout tool. The river basins' data were obtained from the United Nations CEO Water Mandate Interactive Database of the World's River Basins database in shapefile format (see the database: http://riverbasins.wateractionhub.org/). The base map as the "National Geographic Style Map" was also attained from ESRI Living Atlas of the World (to see the base map https://arcg.is/nKiWK).

Figure 1. Afghanistan and the country's domestic and transboundary basins.

Afghanistan has an uneven distribution of its water resources. The Amu Darya Basin, which includes the Harirud and Murghab Basins and non-drainage areas, makes up around 37% of Afghanistan's total land area but is responsible for 60% of its water flow. Only 11% of the water flow is contained in the Helmand Basin, despite it being 49 per cent of the total area. With a 12 per cent area coverage, the Kabul-Eastern River Basin holds around 26% of the water flow (Favre ve Kamal, 2004).

Afghanistan has a wealth of water resources, and its terrain offers numerous options to harness them (Ziaie, 2008). However, Afghanistan's capacity and lack of infrastructure restrict its capability to store, effectively manage, and enhance its water resources. At present, about 65 % of the irrigation systems in Afghanistan are operated by the Mirabs. This traditional system, however, has been facing many challenges due to the effects of modern-day economics changing the values and norms of society (Safi and others, 2016). Moreover, despite the need for regional collaboration, there are no official conversation channels or bilateral or multilateral agreements on the region's transboundary waterways (except for the Iran-Afghanistan treaty on the Helmand River) (Ahmadzai ve McKinna, 2018).

Afghanistan's conflicts have always been fueled by resources, with water being the most divisive. According to a 2013 UNEP assessment, 70–80% of Afghans depend directly on agriculture, animal husbandry, and artisanal mining as sources of income and subsistence

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(Institute for Economics & Peace, 2021). For many generations, violence in Afghanistan has been caused or made worse by access to fertile land and water for agricultural reasons. This conflict also served as a significant motivator for the uprising against the governments of Presidents Hamid Karzai and Ashraf Ghani (Institute for Economics & Peace, 2021). Afghanistan is landlocked; therefore, snowdrifts might provide enough rainfall for all agricultural output if the water were well caught and managed. However, due to conflict, corruption, and general unrest, most of Afghanistan's water is no longer helpful or leaves the nation. Moreover, many people lack easy access to drinking water, even in Afghanistan's largest cities. More than 70% of Kabul's population does not have access to clean drinking water, according to a 2017 report by the Afghan Minister of Urban Development (Institute for Economics & Peace, 2021).

3. Results And Conclusions

3.1. Agriculture, Irrigation and Drought Pattern (1984-2021)

Afghanistan's economy relies heavily on agriculture, which employs a sizable portion of the labour force, accounts for about 60% of all legal exports, and makes up around a quarter of the country's GDP (DeWitt and others, 2022). Afghan agriculture is subject to significant variations depending on the climate and the neighbouring countries' political decisions (Khaliq ve Boz, 2018). In the country, the production of cereals and other annual crops, which makes up an estimated 23% of the agricultural GDP, is vital to the agriculture industry (Khaliq ve Boz, 2018). In Figure 2, the change in the total agricultural area as % of the land area of Afghanistan was given between 1984-2020. (https://data.worldbank.org/indicator/AG.LND.AGRI.ZS?locations=AF).

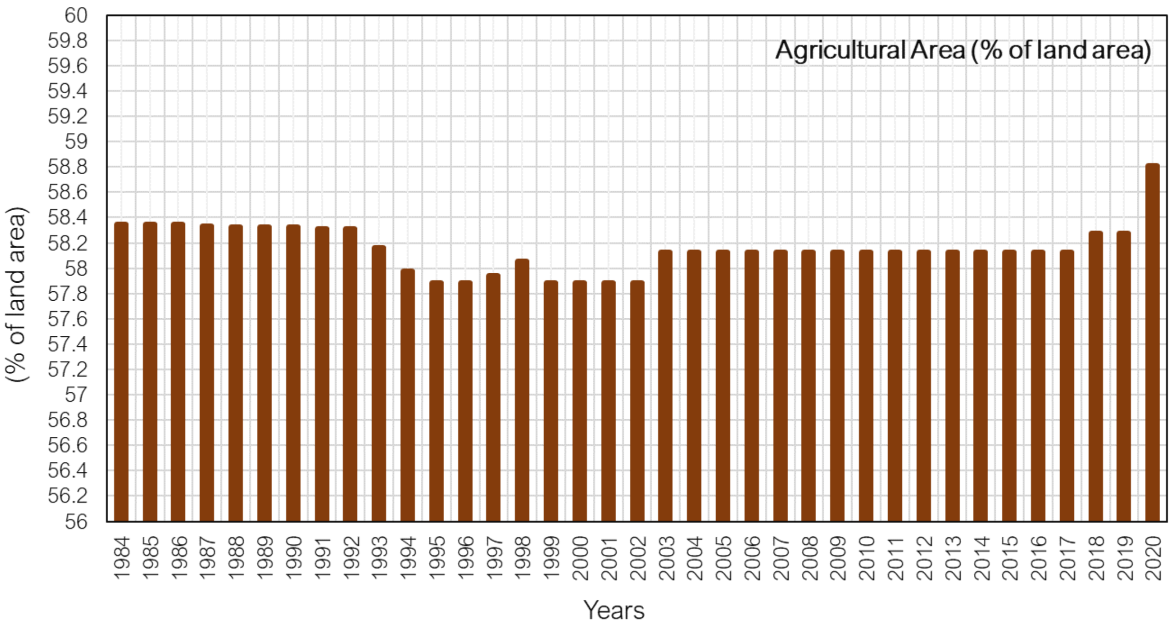
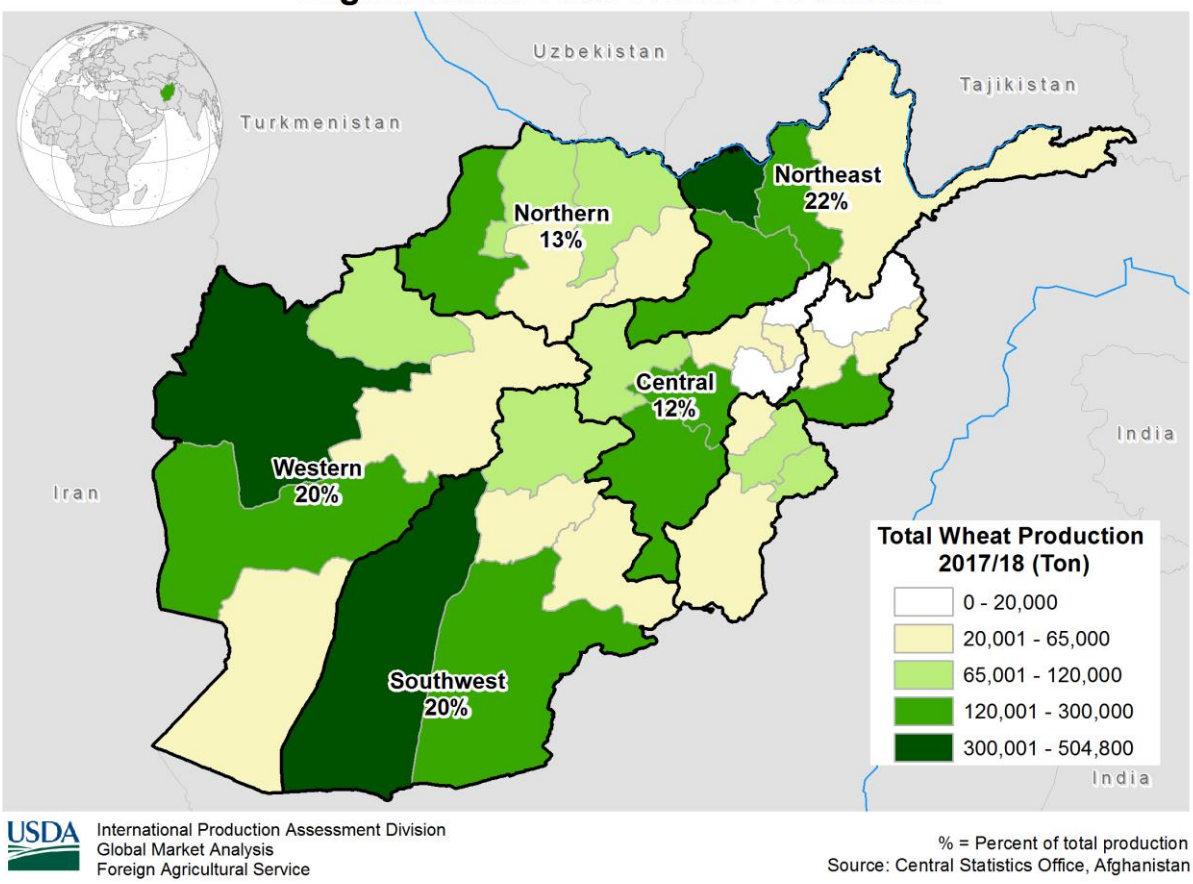


Figure 2. The change of total agricultural area as % of the land area in Afghanistan between 1984 and 2020.

Afghanistan's food security plans heavily rely on the effective use of water and land resources for wheat farming. This is because wheat is an important staple crop in Afghanistan and has a vital cultural significance. A typical Afghan diet contains over 60% of its calories from wheat, compared to 11% from all other grains (Najmuddin and others, 2021). Except for a small portion of Helmand Province, winter grains are farmed mainly in the Northern provinces. The crop is irrigated using snowmelt from the Hindu Kush Mountains (USDA, 2018; Kamil, 2021), accounting for nearly 70% of the yield. However, the remaining winter grains are susceptible to dry conditions (USDA, 2018).

In Figure 3, the wheat production (2017/2018) of Afghanistan was given via using the United States Department of Agriculture (USDA) Foreign Agricultural Service's (FAS) International Production Assessment Division (IPAD) country statistics (source: https://ipad.fas.usda.gov/countrysummary/default.aspx?id=AF&crop=Wheat). In Figure 4, the country's barley, rice, corn and cotton productions were given, respectively.



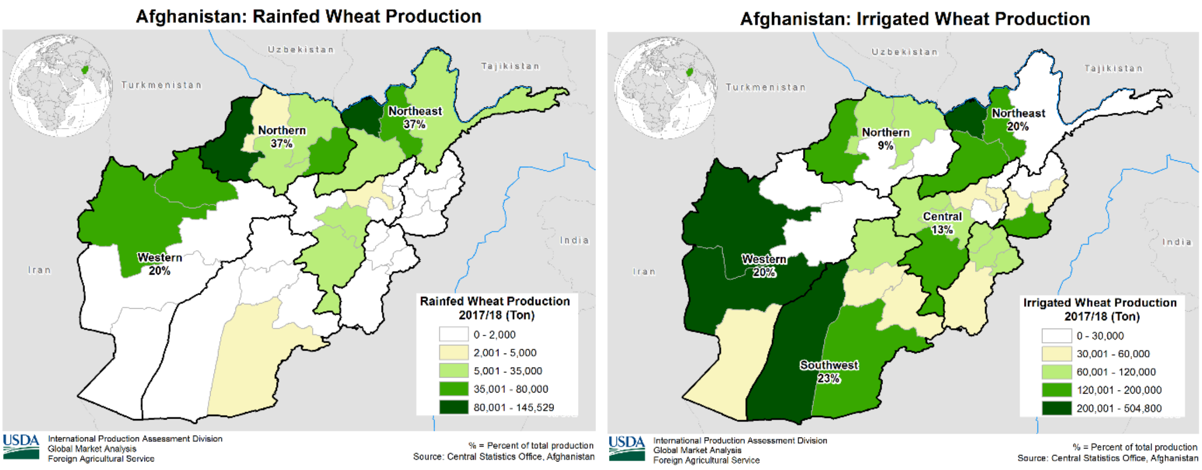


Figure 3. (a) Total wheat production, (b) rainfed and (c) irrigated wheat production in Afghanistan for 2017/2018 (Source: https://ipad.fas.usda.gov/countrysummary/default.aspx?id=AF&crop=Wheat).

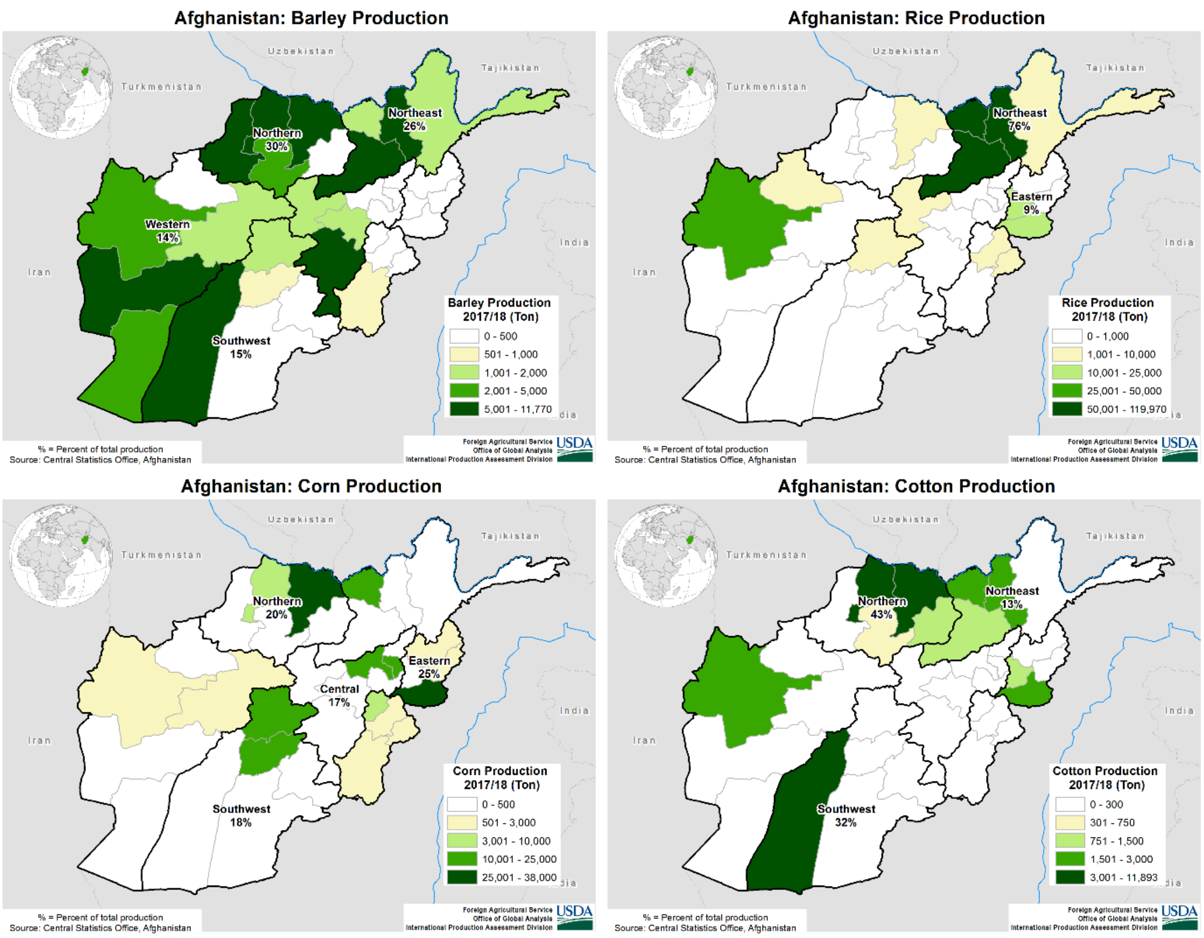


Figure 4. Afghanistan's barley, rice, corn and cotton production for 2017/2018 (Source is available for various crops from this website: https://ipad.fas.usda.gov/countrysummary/default.aspx?id=AF&crop=Wheat).

According to Naimuddin et al. (2021), approximately 2.7 to 3 million hectares of Afghanistan's arable land, or about 80% of the country's total cereal planting area, are dedicated to the production of wheat (Figure 3), which is mainly grown for domestic consumption. Barley and wheat are both grown during the same season and combined are referred to as winter cereals. In terms of production area, barley (in Figure 4) places second to wheat as a rival crop to wheat. Afghan farmers typically choose wheat over barley if they have enough irrigation water and labour (Najmuddin and others, 2021).

In Afghanistan, 90% of agricultural irrigation is also handled through traditional, community-based mirab schemes, which are inefficient and unrelated to larger national or regional frameworks, according to King ve Sturtewagen (2010). For Nengroo (2012), most of Afghanistan's agricultural output comes from its 3 million hectares of irrigated land and gardens. The utilization of 3.5 million more hectares is for non-irrigated production, which is reliant on precipitation. Together, they contribute significantly to the nation's economy, with agriculture making up more than half of the GDP. Similarly, almost 80% of the population works in agriculture, raising cattle. According to Knoema (2022), the total area of Afghanistan that was fitted for irrigation in 2020 was 3,208 thousand hectares. From 2,386 thousand hectares in 1971 to 3,208 thousand hectares in 2020, Afghanistan's total area equipped for irrigation expanded at an average yearly rate of 0.61%. According to Nengroo (2012), over the past 30 years, the overall area that is irrigated has changed. Afghanistan was nearly self-sufficient in food by the middle of the 1970s. About 3.3 million hectares—or around 85% of the nation's total crop production—were cultivated using various irrigation techniques. Due to turmoil and war, droughts, severe flooding, and failure to run and maintain irrigation systems at a local and national level, this has decreased to roughly two million hectares. Figure 5 shows the fluctuations of irrigated agricultural lands as % of the total agricultural area between 2001 and 2020 (to see the

source: https://data.worldbank.org/indicator/AG.LND.IRIG.AG.ZS?locations=AF).

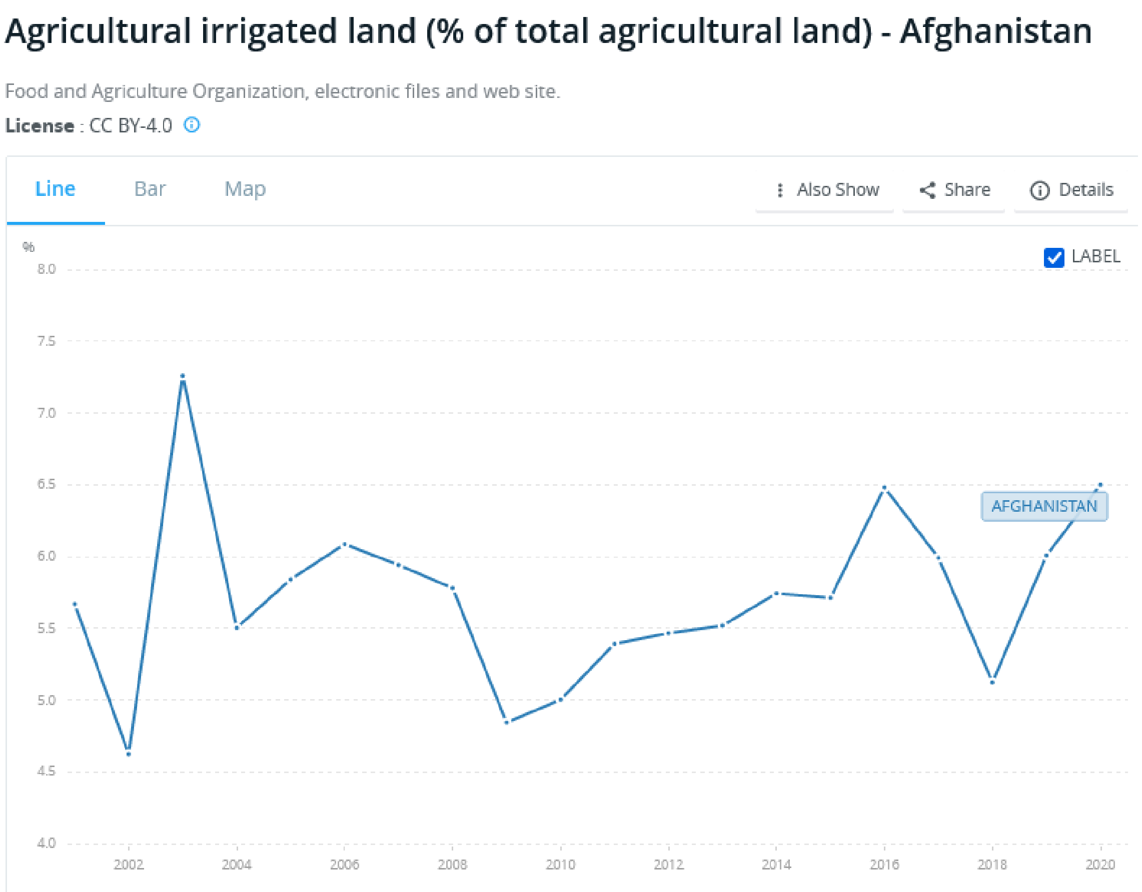


Figure 5. The fluctuations of irrigated agricultural lands as % of the total agricultural area for 2001-2020.

Thirty years of war and unrest have dramatically diminished Afghanistan's water infrastructure and decimated its human capacity in hydrology. Only 1.5 million hectares of agricultural land were irrigated in 2002 (an additional 300,000 hectares have been rehabilitated since), less than half the area irrigated in 1979. Moreover, irrigation schemes are less reliable than in the past. Heavily dependent on seasonal rain and snowfall, Afghanistan's water resources have become unstable. Glacial retreat and early snowmelt have severe effects on seasonal water availability. The country needs new dams to increase storage capacity and improve irrigation efficiency to balance these seasonal shifts. In the near future, Afghanistan will have the region's lowest storage capacity per capita (King ve Sturtewagen, 2010). However, not only wars and internal turmoil have been highly effective in increasing Afghanistan's agricultural stress, but also drought.

Between Figure 6 and Figure 8, the drought intensity for Afghanistan's croplands as an annual summary (1986-2021) was given by using Food and Agriculture Organization (FAO) Global Information and Early Warning System on Food and Agriculture (GIEWS) database. The data are at 1 km resolution for 2007 and after. For 1986-2006, the 1 km data were derived from NOAA-AVHRR (National Oceanic and Atmospheric Administration-Advanced Very-High-Resolution Radiometer) dataset at 16 km resolution (FAO GIEWS, 2022). According to FAO

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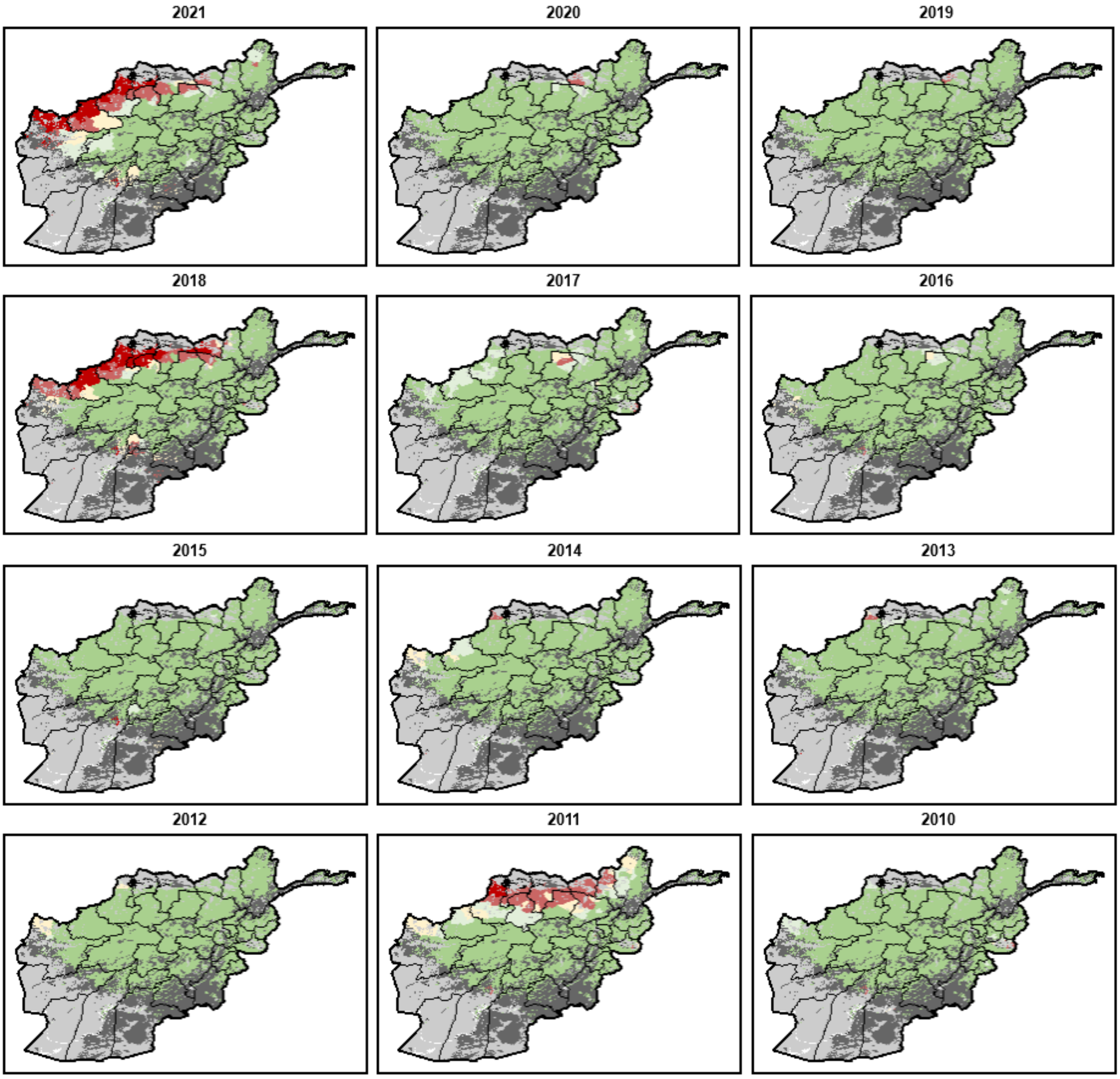
GIEWS's methodology, agricultural droughts are divided into four categories based on severity: Extreme, Severe, Moderate, and Mild. The Weighted Mean Vegetation Health Index, which measures drought severity, shows that the worse the vegetation health, the more intense the drought. Therefore, the user can evaluate the overall severity of the drought for an entire growing season using the Annual summary of Drought Intensity (FAO GIEWS, 2022).



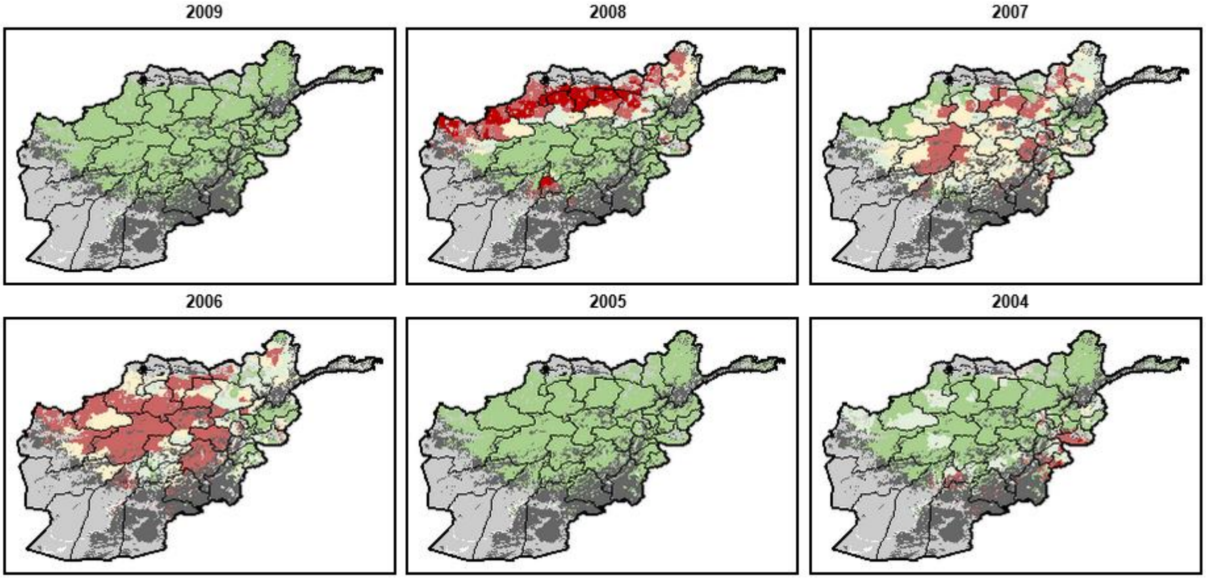
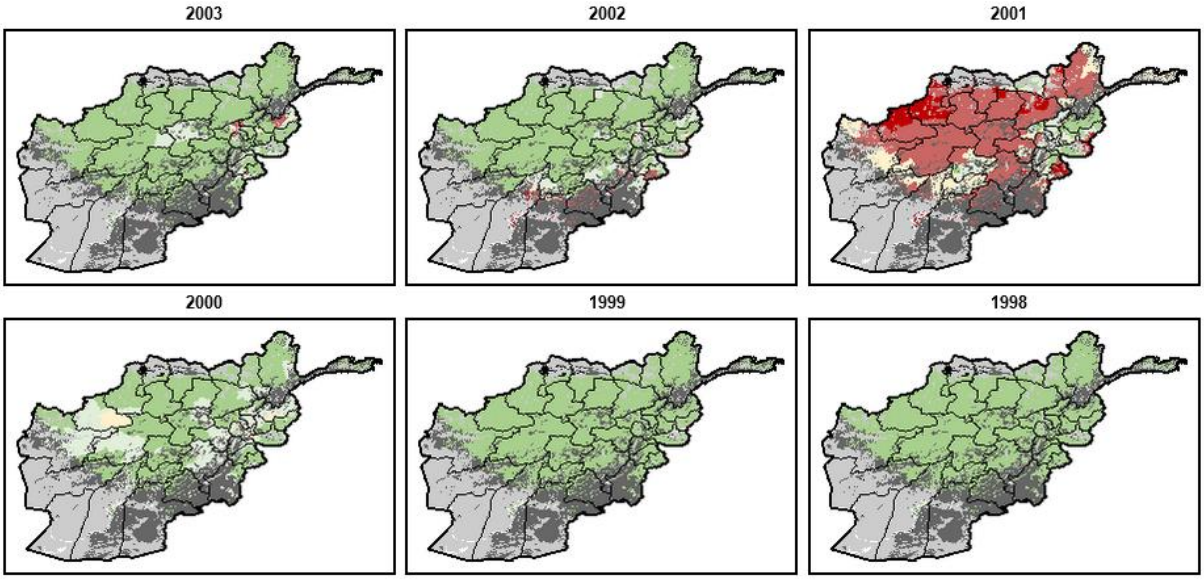


Figure 6. The drought intensity data for 2021/2004 in Afghanistan (data and layout source: FAO GIEWS, 2022).



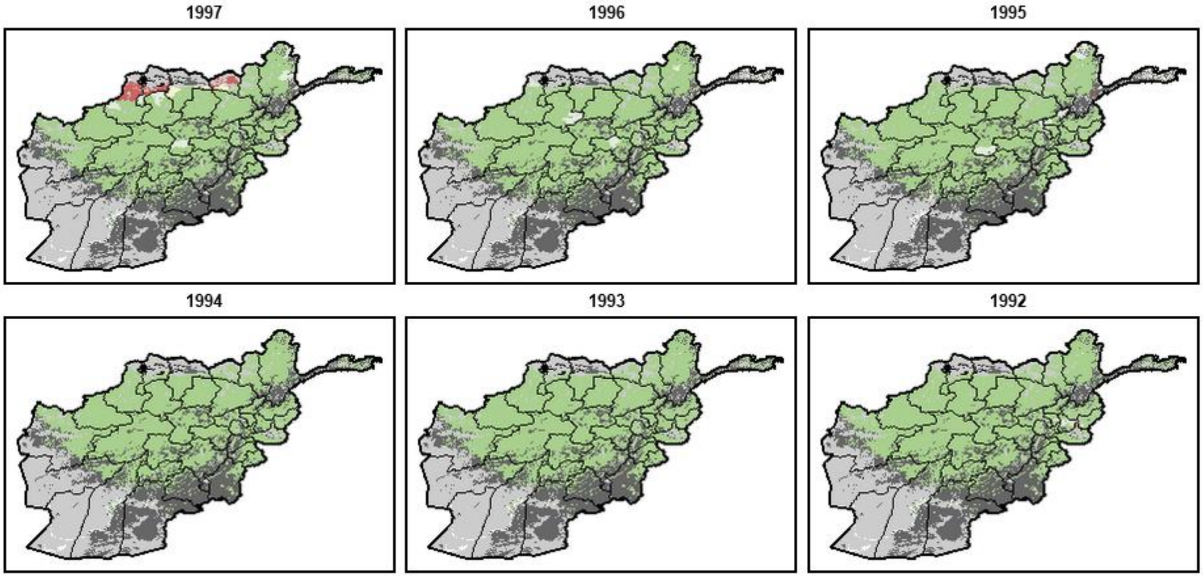


Figure 7. The drought intensity data for 2003/1992 in Afghanistan (data and layout source: FAO GIEWS, 2022).

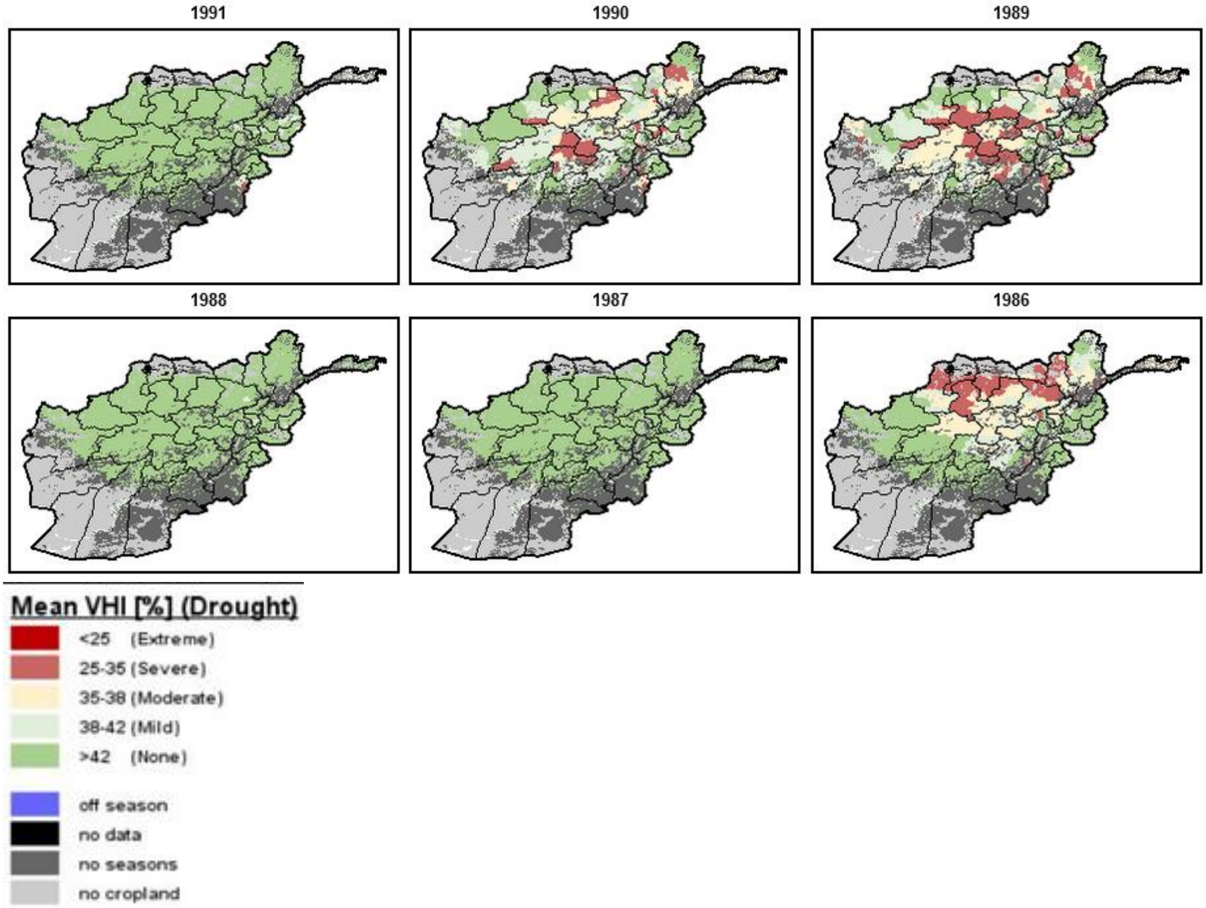


Figure 8. The drought intensity data for 1991/1986 in Afghanistan (data and layout source: FAO GIEWS, 2022).

Looking at the dry years in Afghanistan in 1986, 1989 and 1990, although "extremely arid" regions did not spread to all cropland; generally, the croplands were exposed to drought. Especially the periods of extreme drought are 2001, 2006, 2007 and 2008. In 2011, 2018 and 2021, extremely arid regions remained in the northern croplands. Based on USDA (2018), due to below-average precipitation over north-growing areas, Afghanistan's 2018–19 winter grains crop yield is anticipated to be lower than the previous year. The report's findings are compatible with the present study, which indicated the drought intensity in Figure 8 for 2018. The report (USDA, 2018) states that at 4.0 million metric tons, wheat production in 2018–19 is anticipated to be 20 per cent lower than in 2017. The yield is expected to decline by 18%, and the area is down 2% from the previous year. With a yield predicted to be 1.40 tons per hectare (ton/ha), barley production will be 350,000 metric tons, a decrease of 14% from last year.

In addition to drought, low vegetation health triggers agricultural stress. This can be seen in the Weighted Mean Vegetation Health Index (VHI), which represents vegetation health and is shared by FAO GIEWS (Figure 9). By assessing the health of the vegetation and the impact of temperature on plant conditions, the Annual Weighted Mean Vegetation Health Index (Weighted Mean VHI) enables the user to evaluate the overall severity of drought for a whole growth period. The Annual Weighted Mean VHI evaluates the temporal impact of moisture deficiencies and temperature across the growing season while considering a crop's susceptibility to water stress during its growth period (FAO GIEWS, 2022). The data were obtained from FAO GIEWS in CSV format to analyze the index values. Here, values below 0.25 indicate that the health of vegetation is extremely stressed. Stress is reportedly "reduced" with values of 0.55 and higher, and values indicate "excellent health" near one.

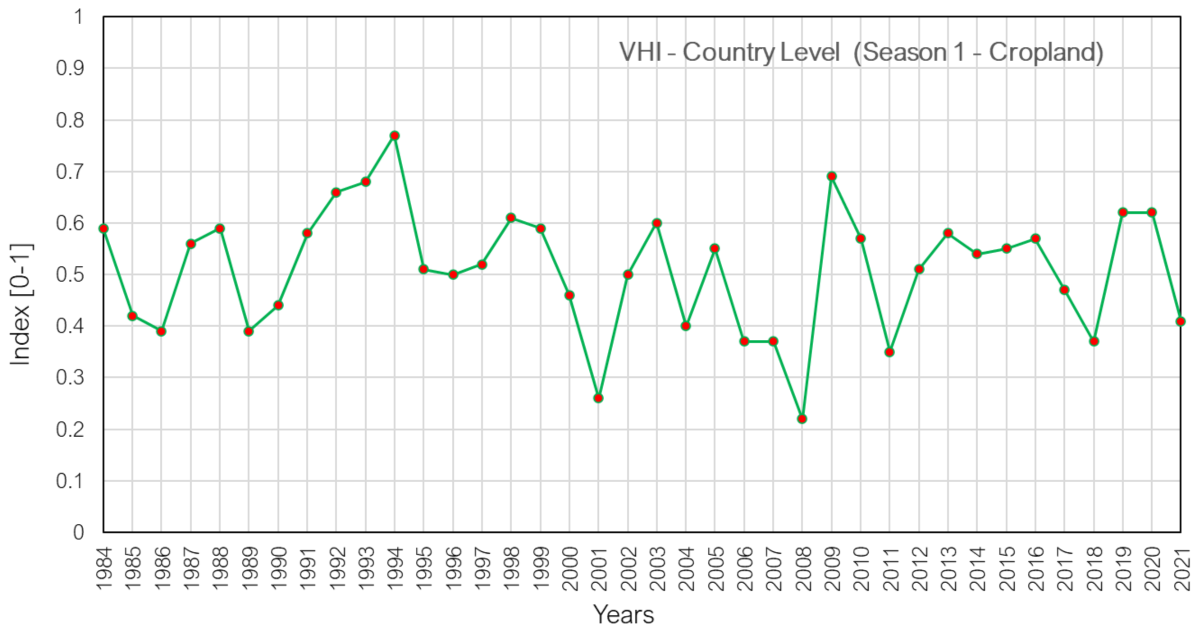


Figure 9. Multi-temporal Vegetation Health Index of croplands in Afghanistan.

According to Figure 9, VHI experienced its lowest level due to drought and water stress in 2008. This year was followed by 2001. The years 1986, 1989 and, 2006, 2007, 2011, 2018, 2021 were also the periods when the index was relatively low, so stress is highly remarkable.

The above explanations are given in which years the VHI values are low due to drought intensity and water stress. These two factors, in particular, directly affect agricultural stress. Agricultural stress in Afghanistan was also determined by the Agricultural Stress Index given by FAO GIEWS (to see the database https://www.fao.org/giews/earthobservation/country/index.jsp?code=AFG&lang=en#). It has been shown that stress increases in similar years because multi-time stress index change is affected by drought and VHI. Significantly, 2001 and 2008 were record-breaking years of agricultural stress (Figure 10).

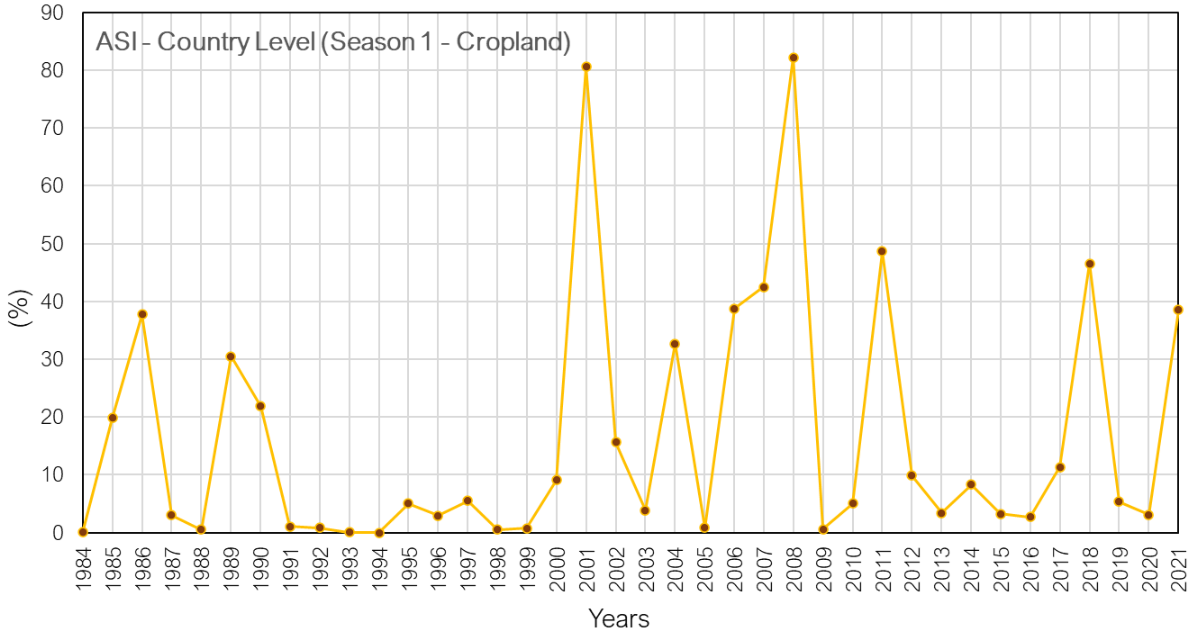


Figure 10. Agricultural Stress Index of Croplands in Afghanistan.

Drought reduced vegetation health and consequent increase in agricultural stress primarily result in an increase in the prices of farm products in the domestic market. In addition, Afghanistan wanted to buy agricultural products from the foreign market during periods of agricultural stress due to both wars and internal turmoil. This situation resulted in an increase in the prices of farm products in the domestic market. In particular, for wheat, the most important agricultural product, the record price increase of the last 12 years was seen in 2008 (Figure 11). Here, multi-temporal wheat price changes were primarily analyzed by FAO Food Price Monitoring and Analysis (FAO FPMA) (to see the dataset https://fpma.fao.org/giews/fpmat4/#/dashboard/tool/domestic) (Figure 11). Subsequently, crisis risks and alarm situations for commodity prices were identified throughout Afghanistan with the Food Price Forecasting and Alert for Price Spikes tool developed by the World Food Programme (the dataset https://dataviz.vam.wfp.org/economic_explorer/price-forecasts-alerts?adm0=1) (Figure 12 and Figure 13).

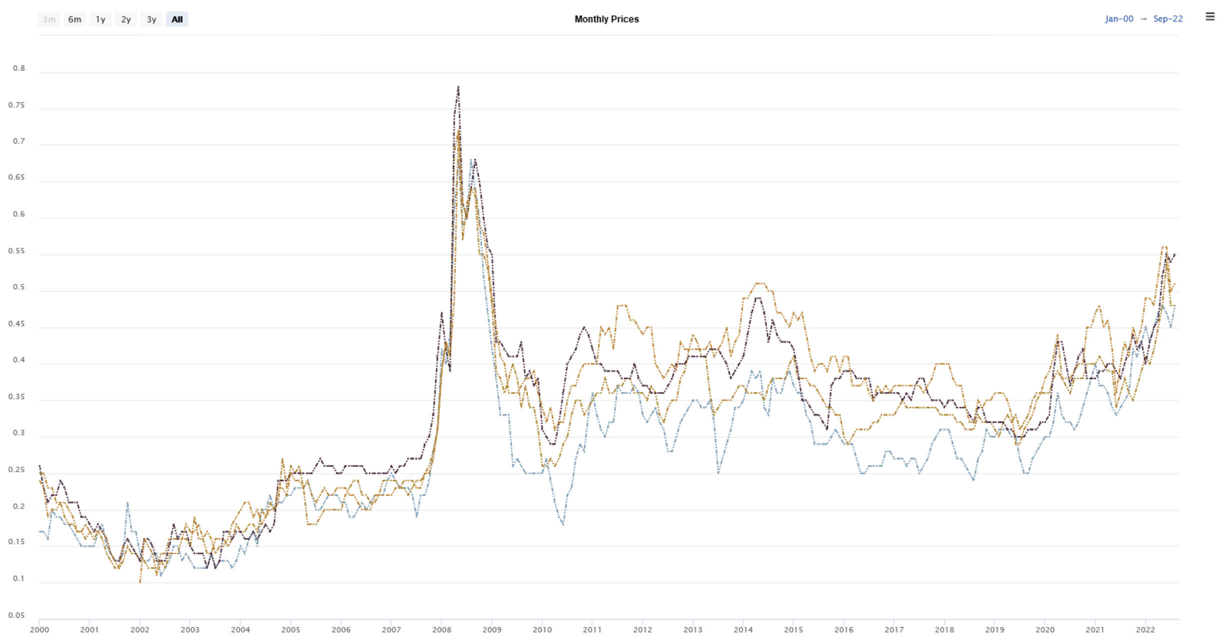


Figure 11. Change in the domestic wheat prices for Afghanistan between 2000 and 2022.

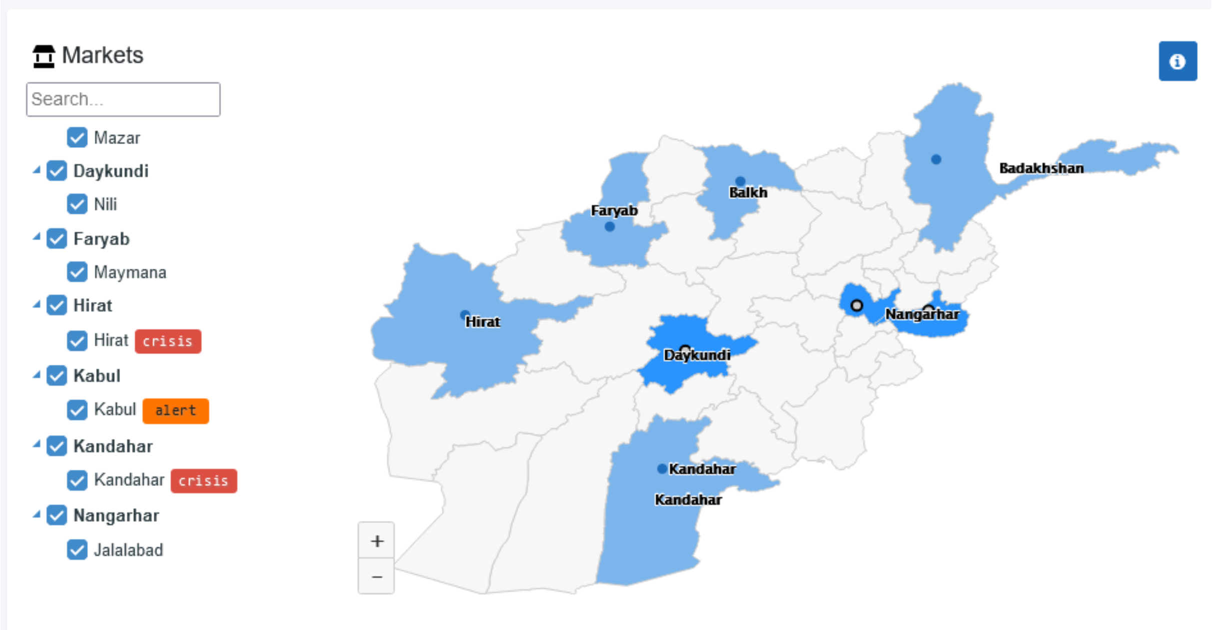


Figure 12. The Food Price Forecasting and Alert for Price Spikes tool's Afghanistan data for crisis and alerts data.

Commodities

Fayzabad market					
Fuel (diesel) *retail*		Apr 20	39.5 AFN/L		
Rice (low quality) *retail*		Apr 20	68.0 AFN/KG		
Wage (non-qualified labour, non-agricultural) *retail*		Apr 20	300.0 AFN/Day		
Wage (qualified labour) *retail*		Apr 20	1000.0 AFN/Day		
Wheat *retail*		Apr 20	31.4 AFN/KG		
Mazar market					
Fuel (diesel) *retail*		Apr 20	40.0 AFN/L		
Rice (low quality) *retail*		Apr 20	43.0 AFN/KG		
Wage (non-qualified labour, non-agricultural) *retail*		Apr 20	300.0 AFN/Day		
Wheat *retail*		Apr 20	29.0 AFN/KG		
Nili market					
Fuel (diesel) *retail*		Apr 20	53.0 AFN/L		
Rice (low quality) *retail*		Apr 20	71.0 AFN/KG		
Wage (non-qualified labour, non-agricultural) *retail*		Apr 20	350.0 AFN/Day		
Wage (qualified labour) *retail*		Apr 20	750.0 AFN/Day		
Wheat *retail*		Apr 20	34.0 AFN/KG		
Maymana market					
Rice (low quality) *retail*		Apr 20	45.0 AFN/KG		
Wage (non-qualified labour, non-agricultural) *retail*		Apr 20	250.0 AFN/Day		
Wheat *retail*		Apr 20	28.5 AFN/KG		
Hirat market					
Bread *retail*	crisis	Oct 22	63.0 AFN/KG		
Fuel (diesel) *retail*	stress	Oct 22	95.0 AFN/L	↓ -6.0	(-6.3%)
Rice (low quality) *retail*	crisis	Oct 22	72.0 AFN/KG		
Wage (non-qualified labour, non-agricultural) *retail*	alert	Oct 22	300.0 AFN/Day		
Wheat *retail*	crisis	Oct 22	45.0 AFN/KG		
Wheat flour *retail*		Jun 19	31.0 AFN/KG		
Kabul market					
Bread *retail*	stress	Oct 22	54.0 AFN/KG		
Fuel (diesel) *retail*		Oct 22	104.0 AFN/L	↑ +12.1	(12%)
Rice (low quality) *retail*		Oct 22	47.0 AFN/KG		
Wage (non-qualified labour, non-agricultural) *retail*	alert	Oct 22	350.0 AFN/Day	↑ +4.0	(1%)
Wheat *retail*	alert	Oct 22	42.0 AFN/KG		
Wheat flour *retail*		Jun 19	30.0 AFN/KG		
Kandahar market					
Bread *retail*	stress	Oct 22	50.0 AFN/KG		
Fuel (diesel) *retail*		Oct 22	95.0 AFN/L	↓ 8.9	(9.3%)
Rice (low quality) *retail*	stress	Oct 22	38.0 AFN/KG		
Wage (non-qualified labour, non-agricultural) *retail*	alert	Oct 22	300.0 AFN/Day	↑ +1.5	(1%)
Wage (qualified labour) *retail*		Oct 22	800.0 AFN/Day	↑ +4.1	(1%)
Wheat *retail*	crisis	Oct 22	51.0 AFN/KG		
Wheat flour *retail*		Jun 19	27.5 AFN/KG		

Jalalabad market		
Bread *retail*	Apr 20	50.0 AFN/KG
Fuel (diesel) *retail*	Apr 20	43.0 AFN/L
Rice (low quality) *retail*	Apr 20	37.0 AFN/KG
Wage (non-qualified labour, non-agricultural) *retail*	Apr 20	300.0 AFN/Day
Wheat *retail*	Apr 20	30.0 AFN/KG
Wheat flour *retail*	Jun 19	32.3 AFN/KG

Figure 13. Food Price Forecasting and Alert for Price Spikes data for Afghanistan domestic markets.

As can be seen from here, there is a crisis, stress or alarm in bread and wheat in Herat, Kabul and Kandahar. Herat is located in the western part of Afghanistan. The country's western part accounts for 20% of total wheat production (see Figure 3a) (USDA IPAD, 2022). In the 2018/2018 season, Herat produced approximately 300,000-504,800 tons of wheat. A large part of this production (200,000-504,800 tons) is irrigated production (Figure 3c). Herat is also second in rice production after the northeastern part of the country (25,000-50,000 tons) (Figure 4). However, as seen in Figure 8, 2018, 2021, that is, the extreme drought experienced in the recent period, especially in the west-north sections, has adversely affected production here and brought production to crisis or alarm status. Kabul is located in the central part of the country. Here, bread is in a state of stress, and wheat is on alert. Central Afghanistan accounts for 12% of total wheat production. Production in Kabul is about 20,000 tons (maximum) (Figure 3a). Almost all of this is irrigated production (Figure 3c). Kandahar is located in the southwest part of the country. Here bread and rice are in a state of stress and wheat crisis. The Southwest section has 20% of the country's total wheat production. The total production for Kandahar is between 120,000 and 300,000 tons (Figure 3a). Of this, 120,000-200,000 tons is irrigated production (Figure 3c). This shows that Kandahar also produces wheat primarily through irrigated agriculture. According to WFP VAM data (https://dataviz.vam.wfp.org/version2/ from Armed Conflict Location & Event Data Project (ACLED), daily data; displaying from the last 30 days), there are strategic developments, violence against civilians and battles in Herat. In Kandahar, explosions and remote violence are observed currently. Kabul's conflicts consist of violence against civilians. These conflicts and the alert situation may cause the vulnerability for agricultural activities just as caused by drought.

3.2. No Development, Peace, and Stability In The Short Term Without Water And Food Security

Without significant advancements in the planning and governance of Afghanistan's water resources, the country won't be able to meet its energy, agriculture, or rural and urban development goals. The Afghanistan National Development Strategy 2008-2013 (ANDS), the centrepiece of Afghanistan's development plan, must have these objectives. (Ziaie, 2008). Therefore, water and irrigation are distinct areas of attention in the ANDS under economic and social development. Afghanistan can benefit from the construction of dams and water infrastructure in several ways, including a reduction in its reliance on foreign hydropower and an increase in the water supply for livestock and agriculture. But to engage in water discussions and offer a stage for conversations and signing official agreements with its neighbour countries, this must be supplemented by competent diplomacy (Sayed ve Sadat, 2022). Nevertheless, it is crucial to acknowledge that neither Afghanistan nor its neighbours have made any concerted efforts to join their formalized frameworks of water cooperation.

On the other hand, Afghanistan is not included in the current regional cooperation frameworks for some of the shared water resources. Therefore, the situation of regional water resources and interstate multilateral cooperation will be significantly impacted in the short and long terms by the absence of transboundary water agreements and institutions between Afghanistan and its surrounding nations (Nori, 2020).

3.3. Water and Food Security Crisis Rise in Afghanistan

Afghanistan is landlocked; therefore, snowdrifts might provide enough rainfall for all agricultural output if the water were well caught and managed. However, due to conflict, corruption, and general unrest, most of Afghanistan's water is no longer helpful or escapes the nation. As a result, many people lack easy access to fresh water, even in Afghanistan's largest cities. (Institute for Economics & Peace. Global Peace Index, 2021).

In the 20th and 21st centuries, Afghanistan had several significant wars. Because of these battles, Afghanistan could not develop its water resources, which flowed to its neighbours without being utilized. Although Afghanistan has started to construct projects in both the agricultural and hydroelectric industries during the past ten years, the Taliban overran the nation in 2021 and halted these initiatives (IESS, 2022). Moreover, natural catastrophes and climate change significantly negatively influence Afghanistan and make it more difficult for the country to develop and achieve peace. Afghanistan's natural resources are threatened by climate change, and continued floods and droughts are predicted to affect agricultural productivity and output. The ongoing conflict has also weakened Afghanistan's ability to respond to ecological challenges since natural calamities put further strain on an already ill-equipped system of government. (Institute for Economics & Peace. Global Peace Index, 2021).

Stakeholders in the Food Security and Agriculture Cluster, such as FAO, the World Food Programme (WFP), and other non-governmental organizations, published an analysis of Phase Classification (IPC) in May 2022. (NGOs). According to the most recent Integrated Food Security report, 19.7 million people -nearly half of Afghanistan's population- experience acute hunger, which means they cannot provide for their daily needs (FAO, 2022). Due to the country's crumbling economy and ongoing drought, high levels of severe food insecurity continue to exist throughout Afghanistan. In addition, the fallout from the conflict in Ukraine is making it more challenging to secure adequate food supplies, driving up the price of staples like food and fertilizer while also putting pressure on the nations that provide Afghanistan with wheat to limit food exports and prioritize local consumption (FAO, 2022).

There is no time to waste, U.N. Secretary-General Antonio Guterres declared during his briefing to the U.N. Security Council on January 26, 2022. Antonio Guterres' goal was to remove the barriers to funding humanitarian aid efforts in Afghanistan. Millions of people, according to Guterres, are starving, and he issued a dire warning that there may be a mass exodus from the nation. Guterres asked for important financial transactions to be permitted for humanitarian help, noting that more than 80% of the population lacks access to fresh water (Nicholson ve Landay, 2022). Due to contamination from several sources, including a lack of river basin infrastructure and regulations governing water resource management, as well as a five-year drought (until 2008) and seasonal flooding, the majority of Afghans struggle to access adequate and safe water supplies (Williams-Sether, 2008). In Afghanistan, where there are currently no comprehensive studies about the quality of the country's water supply, groundwater is the primary source of drinking water.

Furthermore, groundwater typically deteriorates naturally or as a result of human activity. According to the research now available, arsenic, boron, fluoride, and sulfate are significant natural variables that impact the quality of the groundwater in Afghanistan and are problems for public health and even agriculture (Institute for Economics & Peace. Global Peace Index, 2021). Agricultural practices, septic tank systems, household waste, and municipal waste are a few anthropogenic variables that might harm groundwater quality. There were high nitrate concentrations in Ghazni, Helmand, Kandahar, Herat, Ghor, Faryab, Kabul, and Nangarhar; Kabul had Escherichia coli; and Farah, Ghazni, Faryab, Kabul, and Nangarhar had fecal coliforms (Institute for Economics & Peace. Global Peace Index, 2021).

3.4. Concern About the Taliban Disrupts Humanitarian Aid

After the United States and NATO left Afghanistan in August 2021, the Taliban seized power. Taliban fighters invaded Kabul, the Afghan capital, on August 15, 2021 (Barlas, 2022), seizing control of the city and the nation. It was the culmination of a military effort by the Taliban that began in May 2021 and led to that group gaining control of most of Afghanistan, including all of the country's main cities (Institute for Economics & Peace. Global Peace Index, 2021).

Few nations have acknowledged the Taliban's new leadership in Afghanistan. The international community ceased providing aid to Afghanistan because it did not want to cooperate with the Taliban. Donor nations have established strict humanitarian assistance standards, such as human rights adherence. They specified that these requirements must be met for help to be released (United Nations, 2022). Taliban and Afghan civil society delegates met in Oslo, Norway, in January 2022, and they spoke directly with representatives of Norway, the USA, France, and the U.K. The Taliban government was not formally acknowledged due to these contacts, as Norwegian Prime Minister Jonas Gahr underlined in the Security Council meeting on Afghanistan / UNAMA on January 26 2022 (Norway in the U.N., 2022).

3.5. The Current State of Afghanistan Adversely Affects Its Water And Land Resources Development Ability

Afghanistan is currently required to implement hydropower and agricultural projects on waterways. However, significant issues are caused by both the Taliban government and the riparian nations. Afghanistan has persevered in the face of tremendous obstacles. Its survival has been significantly aided by international aid. However, the administration faced new difficulties while attempting to use the nation's resources effectively. According to the World Bank, Afghanistan's overall poverty rate increased from 55% to 72% in 2020 due to the country's declining economy. Most Afghans struggle with poor access to water, sanitation, and hygiene. Only around 27% of the population, according to the UNAMA, has access to fresh water (Bertelsmann Stiftung, 2022). According to the United Nations Environment Program, Afghanistan was experiencing one of the world's most severe humanitarian and environmental disasters (UNEP). Natural disasters in Afghanistan in 2020 put the survival of tens of thousands of families in many districts at risk. The lives of Afghans have also recently been impacted by climate change, which has led to forced migration and greater poverty (Bertelsmann Stiftung, 2022; Sayed ve Sadat, 2022). The Taliban's takeover of the government in 2021 further worsened all the unfavourable circumstances previously mentioned.

Transboundary water resources are another issue Afghanistan confronts with all of its neighbours. For example, it has a conflict with Iran concerning the Helmand Waterway. Because Iran implicitly objected to the agreement and did not follow its terms, although it has a contract with Afghanistan (AA, 2021). Since the fall of the Taliban, the Government of the Islamic Republic of Afghanistan (GIRoA)has been actively trying to resume its hydraulic mission that was put on hold in the late 1970s (Thomas and others, 2016). Improving water control through the construction of dams has been described by the GIRoA as a silver bullet for Afghanistan's development, including food security, hydropower production and mitigating the impacts of droughts and floods (Thomas and others, 2016).

4.Conclusions

Afghanistan values water more than any other natural resource or mineral. All of these factors will increase the demand for water due to climate change, including population growth, urbanization, intensified agricultural, and potential mining operations. Any of its neighbours shouldn't hamper the development of Afghanistan's water resources. Long-term instability in Afghanistan and the surrounding area will result from preventing Afghanistan from constructing energy and agricultural projects on its transboundary rivers. Afghanistan is currently facing economic and hydropolitical obstacles in developing its water projects. Innovative hydropolitics are required in this area to solve these issues. However, it can take a while before the Taliban Regime is acknowledged by the international community and formal negotiations between Afghanistan and its neighbours' start. This period's extension will make the area more unstable.

In this situation, the region needs an immediate plan for short-, medium-, and long-term international support for water and food security. Failure to implement this strategy will harm regional peace and stability and exacerbate Afghan mass migration. Concerns around water development and management must be resolved immediately for Afghanistan's food security. Increasing the number of projects on each of Afghanistan's transboundary river basins may be one approach to achieving this goal. Afghanistan and its neighbours must work together to do this, and the international community must provide financial support, which appears to be challenging in the near future. On the other side, failure to accomplish this objective will contribute to increased regional instability and limit opportunities for meeting the fundamental needs of millions of people in the region.

Water-related national policy initiatives of Taliban Governance will not consider the interests of neighbouring nations if the international community is not involved in the problem. This will make the riparian states more politically stressed. Afghanistan can take a while to gain the confidence and trust of the international community and riparian states. This may prevent Afghanistan from fully realizing its water potential and result in major problems with its food and water security. A creative, forward-thinking foreign aid program and a novel, region-specific hydropolitics strategy are needed in this situation.

To prevent more serious water and food crises and mass migration, the international community needs to consider developing Afghanistan's water resources. It should be mentioned that enhanced regional, as opposed to national, initiatives to develop water resources would benefit Afghanistan and the surrounding region. Furthermore, in a country where 90 per cent of the surface water resources are shared with downstream neighbouring countries, transboundary water resources development should be deeply considered in terms of the interactions between the new Taliban Regime and its riparian neighbours.

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Research Article

National Vulnerability in Wheat's Future: GIS-based Crop Climate Suitability Analysis by CHELSA Climate dataset for Wheat (*Triticum aestivum* L.) in Turkey

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Abstract

Wheat is critical to Turkey's national agricultural production. While the mechanisms by which climate change affects the wheat's spatial suitability, less is known about high-quality climate datasets for climate change-based estimation studies. Using the high-resolution climate dataset CHELSA and two Shared Socio-economic Pathways (SSP126 and SSP370), I sought insights into the future temperature and precipitation projections' impact on the wheat spatial suitability. I observed that the future spatial suitability of wheat is decreasing by more than 40% for all wheat areas (for rainfed/irrigated croplands and 2010-based wheat harvested areas). Moreover, more than 10% of the areas have low suitability within the areas with availability.

In contrast, in low emission (SSP126) and high emission scenarios (SSP370), the most significant difference is seen in the "best suitability" class. These data demonstrate that the suitability of wheat in 2050 (2041–2070 period) will decrease throughout Turkey while suitable areas will be confined to very narrow areas. Due to growing concerns about wheat and food security, future research is urgently needed. Consequently, it is also seen that climate datasets and Crop Climate Suitability Models (CCSM) play an essential role in the projections for crop spatial suitability.

Keywords: climate change, wheat, spatial suitability, CHELSA, climate dataset, Shared Socio-economic Pathways, Geographic Information Systems, Crop Climate Suitability Modelling, vulnerability, Turkey

1. Introduction

The food system is impacted by climate change and non-climatic stresses (such as population growth, rising incomes, and increasing demands for animal products). These climatic and non-climatic stresses affect the four aspects of food security (availability, access, use, and stability) (Kourat and others, 2022). Climate change, which is described as significant long-term changes in meteorological variables like temperature and rainfall, affects food security and accelerates the problems (Sharma and others, 2022). The impacts of a changing climate are a universal occurrence that cannot be avoided. This is concerning since changes in climatic factors impact crop productivity. This is even more alarming given that, by 2050, 9.8 billion people will need food security, which means that cereal production must rise by 70–100% (Sharma and others, 2022).

Cereals need the most land of any crop since they give humans and animals the greatest calories and nutrients. The most significant contributor to the rise in global temperature is human activity, which includes burning fossil fuels, deforestation, and changes to land cover (MacCracken, 2008; Fatima and others, 2020; Sharma and others, 2022). Additionally, droughts have lasted longer and been more intense during the twenty-first century, resulting in a fivefold decrease in agricultural water supplies (Aydin and others, 2020; Sharma and others, 2022). By 2050, the global mean temperature will continue to climb by 1.50 °C (Sharma and others, 2022).

According to the crop, the region, the amplitude, and the shift in the climatic variables, the severity of the impact of the climate on yield varies. Therefore, the effects of global warming are uneven, especially in countries with large areas. Nevertheless, the scientific community generally thinks that the current trends would be suitable for Russia, Ireland, Canada, and Finland in cereal output but harmful for tropical and subtropical regions of Africa, the Middle East, South and Southeast Asia (Sharma and others, 2022). This suggests that climate change reveals the winning or losing species and countries (Aydın ve Sarptaş, 2018; Demir ve Aydin-Kandemir, 2022).

Turkey, in particular, depends heavily on wheat production, primarily grown in rainfed environments (Vanli and others, 2019). In 2022, the annual wheat production in Turkey was approximately 17 million tonnes (Index mundi, see https://www.indexmundi.com/agriculture/?country=tr&commodity=wheat&graph=production; United States Department of Agriculture, 2022) (Figure 1a). Although the annual growth rate decreased in 2021, it increased in 2022 (Figure 1b). The top annual growth rates were also in 1971, 1975, 1990 and 2015.

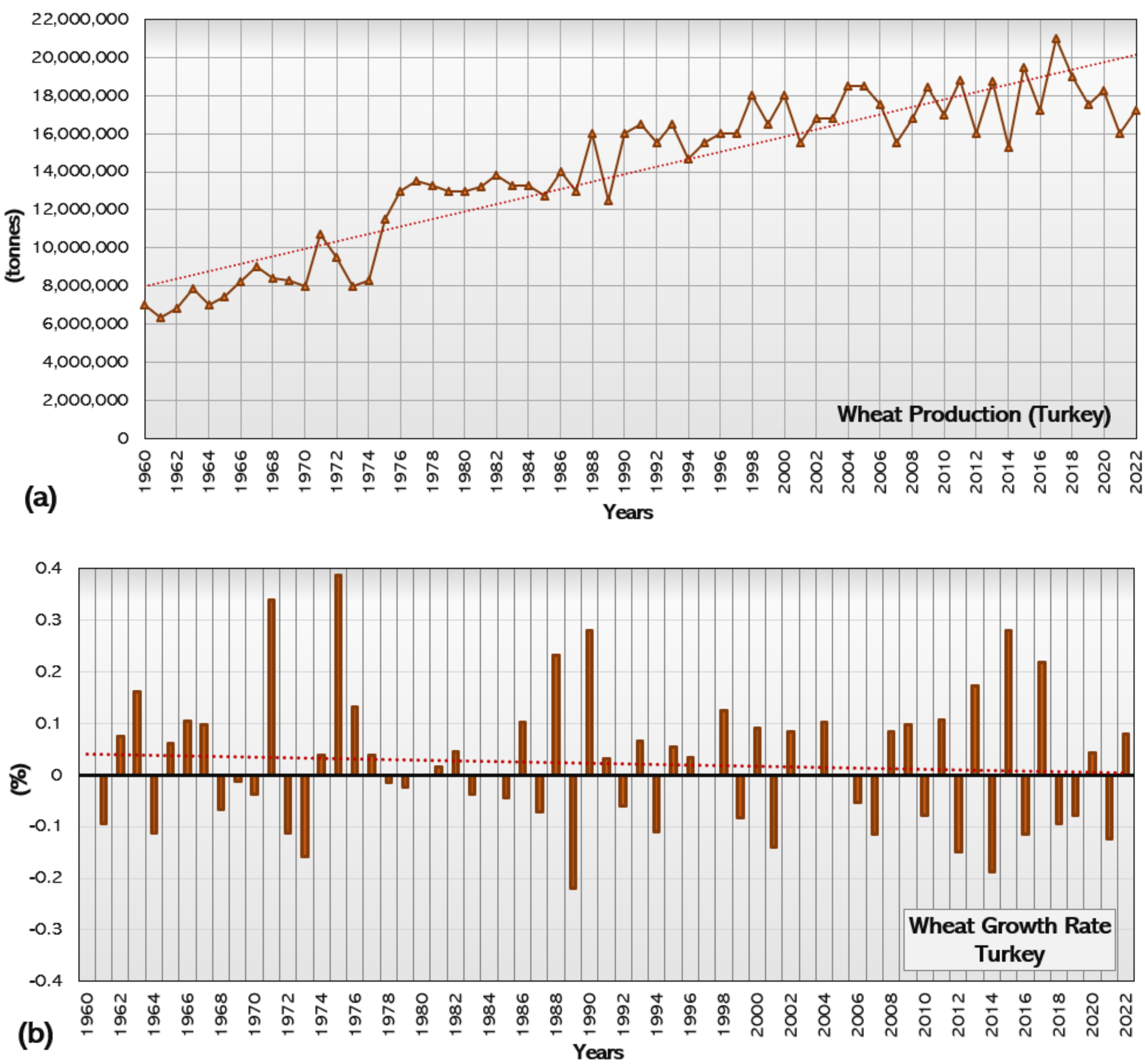

Figure 1. Wheat production in tonnes in Turkey (a) and annual growth rate (b).

Wheat yield decreases under arid and semi-arid climates due to variations in temperature and rainfall patterns. Rising temperatures generally reduce growth time and speed up phenological processes. The length of the growing season was found to be shortened by high temperatures, which in turn reduced wheat output by lowering light interception, grain number, and grain size. For example, a 2 °C increase in temperature and a 35% decrease in precipitation will cause a decline in wheat output of between 12 and 20% in northeastern Turkey between 2040 and 2060 (Vanli and others, 2019).

Various research on wheat crop vulnerability to climate change has been conducted based on GIS. To project the geographic-climatic adaptability of maize, safflower, canola (rape), cotton, wheat, and switchgrass for 2070, for instance, Aydın ve Sarptaş (2018) used a study, and the present and future conditions were compared. To create the climatic suitability maps for each crop for the present and the future, they used the Terrset Climate Change Adaptation

Modeler's Crop Climate Suitability Modelling sub-model with climate data from the average of 1950–2000 (for the present) and HADGEM2-ES GCM's RCP 8.5 (for the future). To assess the effects of climate change on wheat in Turkey's southeast, Vanli and others (2019) conducted a study. Data from eight examined farms were used to calibrate and assess the CERES-wheat crop simulation model. Four farms were used for analysis, and the other four for adjustment. For the research sites in Islahiye and Nurdagi, climate change scenarios were created for the middle of the 21st century (2036-2065) and the end of the century (2066-2095) under typical concentration trajectories (RCPs 4.5 and 8.5). The influence of future climate change on rainfed durum wheat, an essential crop in Algeria, was evaluated by Kourat and others (2022). They used the AquaCrop crop model and the downscaled EURO-CORDEX climate predictions with the ICHEC KNMI model under RCP 4.5 and RCP 8.5 to examine the effects of climate change on the rainfed Mexicali wheat cultivar. They used a delta method to fix the uncertainties in two experimental sites in Algeria's Eastern High Plains, Sétif and Bordj Bou Arreridj (BBA), raw climatic forecasts (EHPs). Sharma et al. (2022) studied how the daily maximum temperature (Tmax), daily minimum temperature (Tmin), and rainfall affected the yield of the three main cereal crops in the Southeast United States: corn (*Zea mays* L.), rice (*Oryza sativa* L.), and wheat (*Triticum aestivum* L.). The authors used a fixed-effect model (panel data approach) to apply the production function on panel data from 1980 to 2020 from 11 southeastern United States (SE-US) states.

In addition to some crop suitability models, some climate data sets are used to assess the wheat's future vulnerability, such as Worldclim (Aydın ve Sarptaş, 2018) and Marksim (Dhakal and others, 2018). In the studies, high-resolution climatic data are essential to many questions and applications, mainly in environmental research and ecology (Karger and others, 2017).

A credible prediction of these changes must be based on reliable data on climate-related variables, considering various climate change scenarios. To close the knowledge gaps about the effects of climate change on the Earth system, pertinent climate-related data with high spatiotemporal resolution must be made available for both the current situation and the decades to come (Brun and others, 2022). Since climatologies with high resolution for the Earth's land surface areas are a famous repository for climate data, ecological studies require unique and powerful initiatives like CHELSA (Brun and others, 2022). The Swiss Federal Institute for Forest, Snow and Landscape Research WSL is now hosting the global downscaled climate data collection CHELSA (Climatologies at high resolution for the Earth's land surface areas), which has a very high resolution (30 arcsec, or 1 km). It is continually updated and improved to offer free access to high-resolution climate data for research and application. It has climate layers for various times and conditions, from the Last Glacial Maximum to the present and several possible futures. The freely accessible CHELSA system is based on a mechanical statistical downscaling of global reanalysis data or global circulation model output (CHELSA-climate, 2022).

This study aims to combine the wheat geospatial suitability analysis with high resolution dataset CHELSA for accurate and reliable results for Turkey in future projections because wheat production consists of the fundamental agricultural activities of the country. Therefore, the results are crucial to interpret the future national vulnerabilities, agricultural water usage and agricultural water utilization projections. Subsequently, agricultural water management can be discussed for the country's wheat cultivation activities.

2. Material And Methods

2.1. Database Definition

In this study, geospatial wheat suitability was assessed by Crop Climate Suitability Model (CCSM) with CHELSA climate data as monthly minimum temperature (Tasmin (°C)), monthly mean temperature (Tas (°C)) and monthly total precipitation (Pr) for 2041-2070 period in Turkey.

The study used the CHELSA V2 for the climatic suitability analysis. CHELSA (Climatology at high resolution for the Earth's land surface areas) is a very high resolution (30 arcsec, ~1km) global downscaled climate data set currently hosted by the Swiss Federal Institute for Forest, Snow and Landscape Research WSL. It is built to provide free access to high-resolution climate data for research and application and is constantly updated and refined (Karger and others, 2017; Stefanidis and others, 2022). In the present study, the Coupled Model Intercomparison Project (CMIP)6 scenario was preferred as MPI-ESM1-2-HR in the CHELSA environment.

The Max Planck Institute for Meteorology has a track record of creating adaptable, cutting-edge climate models (Roeckner and others, 1989). MPI climate models support the following research, both within the institute and globally: The model code is freely accessible for academic research and takes part in some group model comparisons, including the Coupled Model Intercomparison Project's impending sixth phase (CMIP6; Eyring and others, 2016; Mauritsen and others, 2019). In addition, the model is used to solve various scientific and practical issues, all of which involve unique computational demands that are mostly determined by the horizontal resolution of the atmosphere and ocean, as well as difficulties in describing processes or occurrences. Five different coupled model setups with a wide range of computing costs (coarse resolution CR, low-resolution LR, higher resolution HR, ocean-eddy resolving ER, and very high-resolution XR) were developed (Mauritsen and others, 2019).

This study selected Shared Socio-economic Pathways (SSP) 1-2.6 for low Greenhouse Gas (GHG) emissions scenario and SSP 3-7.0 for high GHG scenario to integrate the CCSM interface. The SSP1, in this case, stands for Sustainability - Choosing the Green Way. Slowly but surely, the globe is moving toward a more sustainable course, stressing more inclusive development that honours perceived natural constraints. The management of the global commons gradually gets better, expenditures in education and healthcare speed up the demographic change, and the focus turns from economic growth to a broader emphasis on human well-being. Inequality is declining within and within countries, driven by a growing commitment to reaching development goals. Low material growth and low resource and energy intensity are the main goals of consumption (Hausfather, 2018). Around 2075, according to SSP 1-2.6, the CO_2 emissions will be net zero. This scenario projects warming of

1.7°C for 2041 to 2060, 1.8°C for 2081 to 20100, and quite likely between 1.3 and 2.4°C for 2081 to 2100. (IPCC, 2021).

SSP3 stands for Regional Rivalry - A Rocky Road, on the other hand. Countries are being pushed to concentrate more on internal or, at most, regional issues by a resurgence of nationalism, worries about competitiveness and security, and regional conflicts. Over time, policies change to become more focused on global and domestic security issues. Countries prioritize regional growth at the expense of accomplishing their own regions' energy and food security goals. Investments in technological advancement and education are declining. Inequalities endure or worsen over time, spending is materialistic, and economic development is gradual. Population growth is high in emerging nations and low in industrialized countries. Environmental issues receive little international attention, which causes severe environmental degradation in some areas (Hausfather, 2018). By 2100, the CO_2 emissions in SSP 3-7.0 will have doubled. This scenario predicts warming of 2.1°C for 2041 to 2060, 3.6°C for 2081 to 20100, and quite likely between 2.8 and 4.6°C for 2081 to 2100. (IPCC, 2021).

In the study, the current cropland data was also taken as the basis for comparing the results with today. For this, the United Nations Food and Agriculture Organization's (UN FAO) Land Cover Classification System (LCCS) dataset provided by Copernicus Climate Change Service was examined (CDS, 2022). The spatial resolution of this dataset is 300 m, and temporal coverage from 1992 to the present with one year delay (CDS, 2022). In addition, 2020 land use data was downloaded from the dataset and integrated into GIS software for the study. The land use classes listed here are given in Figure 2.

Value	Label	Color	RGB
0	No Data		0, 0, 0
10	Cropland, rainfed		255, 255, 100
20	Cropland, irrigated or post-flooding		170, 240, 240
30	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)		220, 240, 100
40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)		200, 200, 100
50	Tree cover, broadleaved, evergreen, closed to open (>15%)		0, 100, 0
60	Tree cover, broadleaved, deciduous, closed to open (>15%)		0, 160, 0
70	Tree cover, needleleaved, evergreen, closed to open (>15%)		0, 60, 0
80	Tree cover, needleleaved, deciduous, closed to open (>15%)		40, 80, 0
90	Tree cover, mixed leaf type (broadleaved and needleleaved)		120, 130, 0
100	Mosaic tree and shrub (>50%) / herbaceous cover (<50%)		140, 160, 0
110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)		190, 150, 0
120	Shrubland		150, 100, 0
130	Grassland		255, 180, 50
140	Lichens and mosses		255, 220, 210
150	Sparse vegetation (tree, shrub, herbaceous cover) (<15%)		255, 235, 175
160	Tree cover, flooded, fresh or brackish water		0, 120, 90
170	Tree cover, flooded, saline water		0, 150, 120

Value	Label	Color	RGB
180	Shrub or herbaceous cover, flooded, fresh/saline/brackish water		0, 220, 130
190	Urban areas		195, 20, 0
200	Bare areas		255, 245, 215
210	Water bodies		0, 70, 200
220	Permanent snow and ice		255, 255, 255

Figure 2. The LC maps ' level 1 (or global) legend based on the UN-LCCS (Source: CCCS, 2021).

In the study, 10. class in Figure 2 were treated as rainfed cropland, and 20. class were treated as irrigated cropland. It is based on the fact that these areas are potential wheat cultivation areas today.

In this study, apart from the above-mentioned 2020 land use data, Global Agro-ecological Zones (GAEZ) data to be evaluated directly as the wheat area was also used. This data is most recently included in the database for the year 2010. GAEZ v4 Data Portal is a portal of the Food and Agriculture Organization (FAO) (see the dataset https://gaez.fao.org/pages/data-viewer-theme-5). The data sub-theme was Actual Yields and Production, and spatial layers have five arc-minute resolutions for 26 major crops/crop groups, separately in rain-fed and irrigated cropland. Country totals are based on FAO statistics for the years 2009-2011. Also included are estimates of the spatial distribution of total crop production value and the production values of major crop groups (cereals, root crops, oil crops), all valued at the year 2000 international prices, separately for rain-fed and irrigated cropland (FAO, 2022). In this study, harvested area value was not taken on a pixel basis as the amount of harvest area; instead, each area where the harvest was made was evaluated as the wheat area on a spatial basis.

2.2. Crop Climate Suitability Modelling (CCSM)

The model used in the study is an analysis method in which temperature and precipitation parameters and plant-based temperature and precipitation requests are used. The model, which is based on the climatic suitability of plants, was applied in DIVA-GIS as a method/model developed by Hijmans and others (2001) in 2001 (Aydın, 2015). Ramirez-Villegas and others (2013) calibrated this model in 2011 (Eastman, 2015; Eitzinger and others, 2018). The model's working principle is that temperature and precipitation suitability on an areal or geographical (spatial) basis are determined separately according to the suitability of the plant for growing (plant ecological demands). As a result, the climatic suitability of the region is calculated according to the determined temperature-precipitation suitability (Aydın ve Sarptaş, 2018).

The plant ecological requirements integrated into the model in the study were Tmin (absolute minimum temperature average), Topmin (optimal minimum temperature average), Topmax (optimal maximum temperature average), and Tmax (absolute maximum temperature average); Pmin (absolute minimum precipitation average), Popmin (optimum minimum precipitation average), Popmax (optimum maximum precipitation average), Pmax (absolute precipitation average), and Tkill (killing temperature) (Aydın, 2015; Aydin ve Sarptas, 2018; Demir ve Aydin-Kandemir, 2022). Climate datasets for SSPs (SSP126 & SSP370 MPI-ESM1-2-

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HR) include the monthly average minimum temperature (°C) Tmin, monthly average maximum temperature (°C) Tmax, and monthly total precipitation (mm) Ptot for 12 months of the year (for future climate projections) for (Aydın ve Sarptaş, 2018; Demir ve Aydin-Kandemir, 2022) (Figure 3).

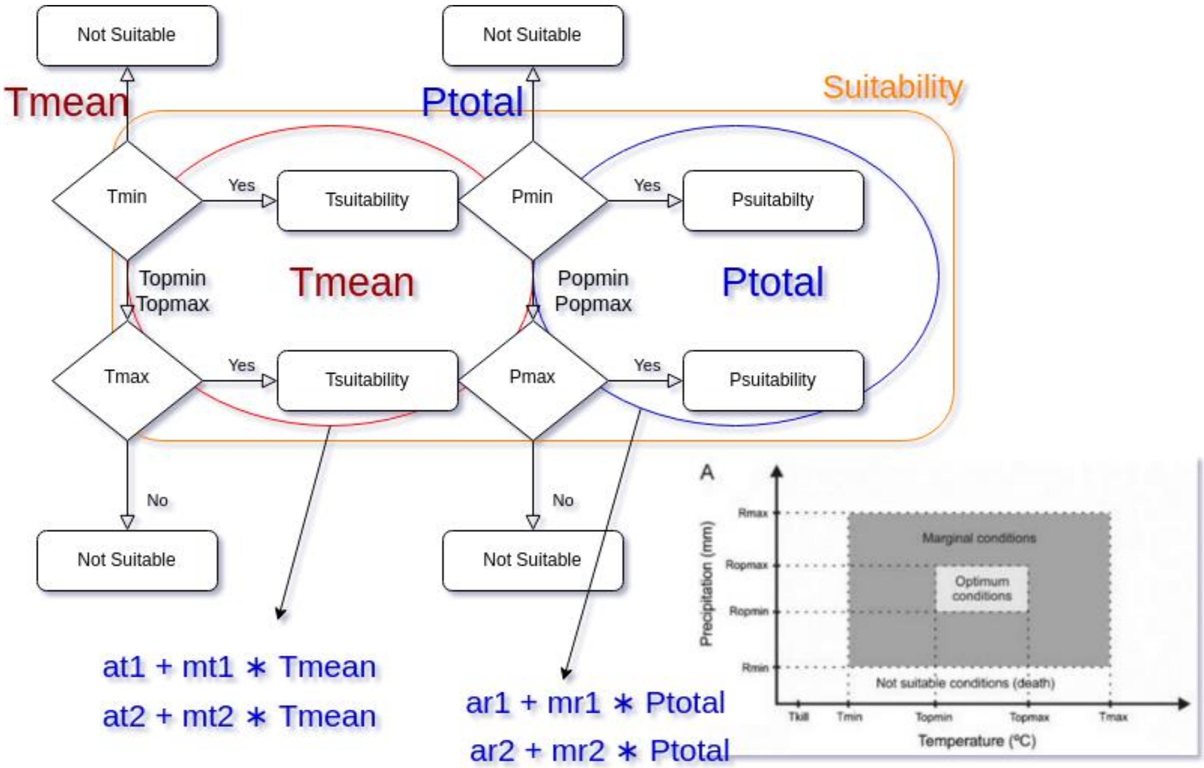

Figure 3. CCSM configuration illustrated via draw.io software in the PARDUS environment.

In Figure 3, if the Tmean value, which is the temperature parameter, falls within the range of Tmin and Tmax, which are the ecological requirements of the plant, the temperature suitability is calculated by the formulas specified in blue. If Tmean falls within the range of Topmin and Topmax, the suitability is 100% for the temperature parameter. Where at1 and mt1 represent the intersection and slope of the regression curve between [Tmin,0] and [Topmin, 100], respectively; at2 and mt2 give the intersection and slope of the regression curve between [Topmax,100] and [Tmax,0], respectively (Laderach ve Eitzinger, 2013; Aydın ve Sarptaş, 2018). The same approach is followed for precipitation. If Ptotal is located between Popmin and Popmax, the precipitation suitability is 100%. Optimum conditions prevail in the region where Tmean and Ptotal are in the optimum temperature and precipitation range, while the maximum temperature and precipitation limit represent marginal conditions. The climatic suitability value is determined by calculating temperature and precipitation suitability separately and multiplying these conformity values (Aydın ve Sarptaş, 2018).

For this investigation, values for the CCSM's plant ecological demand parameters were acquired from the Ecoocrop database. The Food and Agriculture Organization of the United Nations (FAO) created the Ecocrop database in 1992, mainly used to assess a crop's appropriateness for a given environment. This program already has a library of the environmental demands for various crops and species; therefore, it can be used for crops in any place by altering the necessary climatic factors. The creators preserved the whole dataset of these ecological requirements libraries two years ago, despite the fact that this database has been inactive (offline) for several months. Readers can use the R-tool to access these libraries. (ecocrop: Ecocrop Model, 2022; Demir ve Aydin-Kandemir, 2022). Accordingly, the parameters of the ecological requirements for wheat are given in Table 1.

Table 1. Ecocrop-based crop ecological requirements for wheat (ecocrop: Ecocrop Model, 2022).

Wheat (common) - *Triticum aestivum* L.									
T (°C)						**P (mm)**			
Tkill	**Tmin**	**Topmin**	**Topmax**	**Tmax**		**Pmin**	**Popmin**	**Popmax**	**Pmax**
0	5	15	23	27		300	750	900	1600
Gmin	**Gmax**	**Gused**							
90	250	170							

Tkill: absolute temperature that kills the crop
Gmin: minimum days of the growing season
Gmax: maximum days of the growing season
Gused: Average growing season

In the study, the software used to run Crop Climate Suitability Modelling (CCSM) was Terrset, developed by Clark Labs (Eastman, 2015) and the Crop Climate Suitability Model, which is a submodule of the Climate Change Adaptation Modeler (CCAM) here, was used. Terrset software was again used in the analysis of the suitability results. In addition, ArcGIS v2.18 (Environmental Systems Research Institute, 2022) was used to map the results, and the results were mapped based on the GCS global coordinate system and the WGS 84 datum.

3. Results and Conclusion

In this study, using the CHELSA dataset, the spatial suitability of wheat for both SSP126 and SSP370 for the year 2050 (according to the reference 2041-2070) was analyzed by CCSM. The study included separate analyses for the two SSPs. Classes included in the suitability results; (1) Low suitability (0-0.25), (2) Moderate suitability (0.25-0.50), (3) Good suitability (0.50-0.75) and (4) Best suitability (0.75-1.00). In the first stage of the study, the overall CCSM result for SSP 126 is given (Figure 4).

Areas of the suitability classes included in Figure 4, regardless of the land use range throughout the country, Low suitability: 10,980,922 ha, Moderate suitability: 19,585,302 ha, Good suitability: 10,263,250 ha and Best suitability: 1,887,064 ha.

In the study, the results in Figure 4 were subjected to detailed analysis according to the places used as cropland today. The rainfed and irrigated cropland land use classes in the 2020 data from UN-LCCS land use data were taken as the basis. These two land use classes were omitted from the data of all land use classes and coincided with the result in Figure 4.

According to UN-LCCS data, there was 10,769,659 ha of rainfed cropland in Turkey in 2020. Within this area, the areal distribution of suitability classes is 1,622,631 ha for Low suitability, 2,458,536 ha for Moderate suitability, 1,050,285 ha for Good suitability and 196,418 ha for Best suitability. The total suitability scored area constitutes 5,327,870 ha (49.47% of the total rainfed cropland area). The distribution of suitability classes within the rainfed cropland is given in Figure 5.

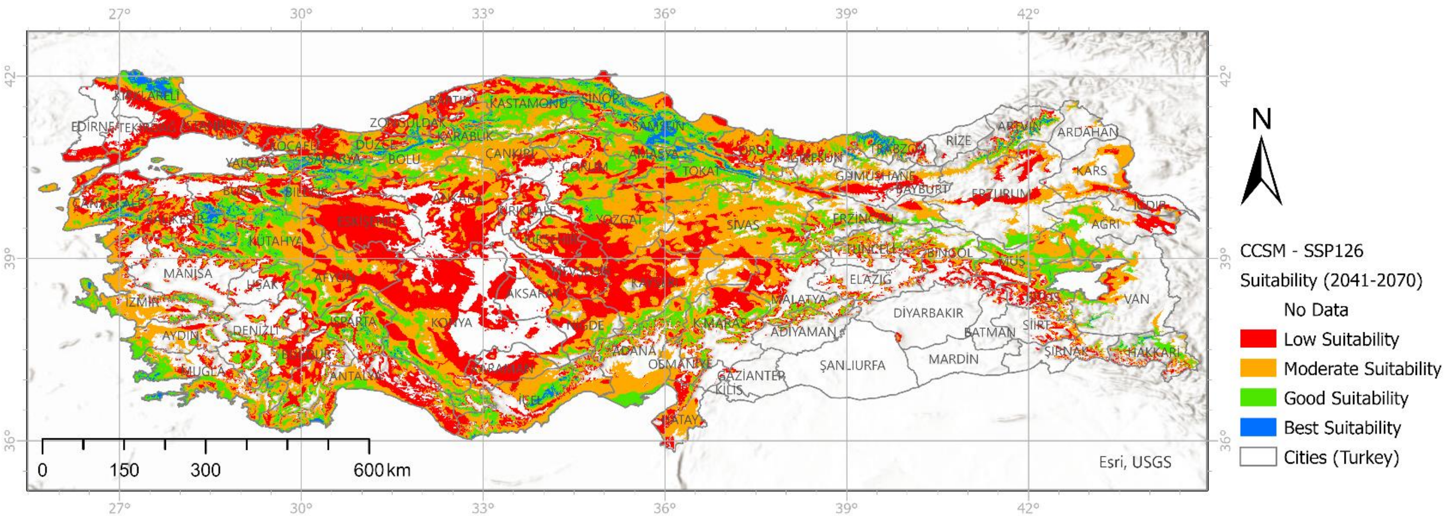

Figure 4. General CCSM results for 2050 (2041-2070 period) with SSP126-based temperature and precipitation data analysis.

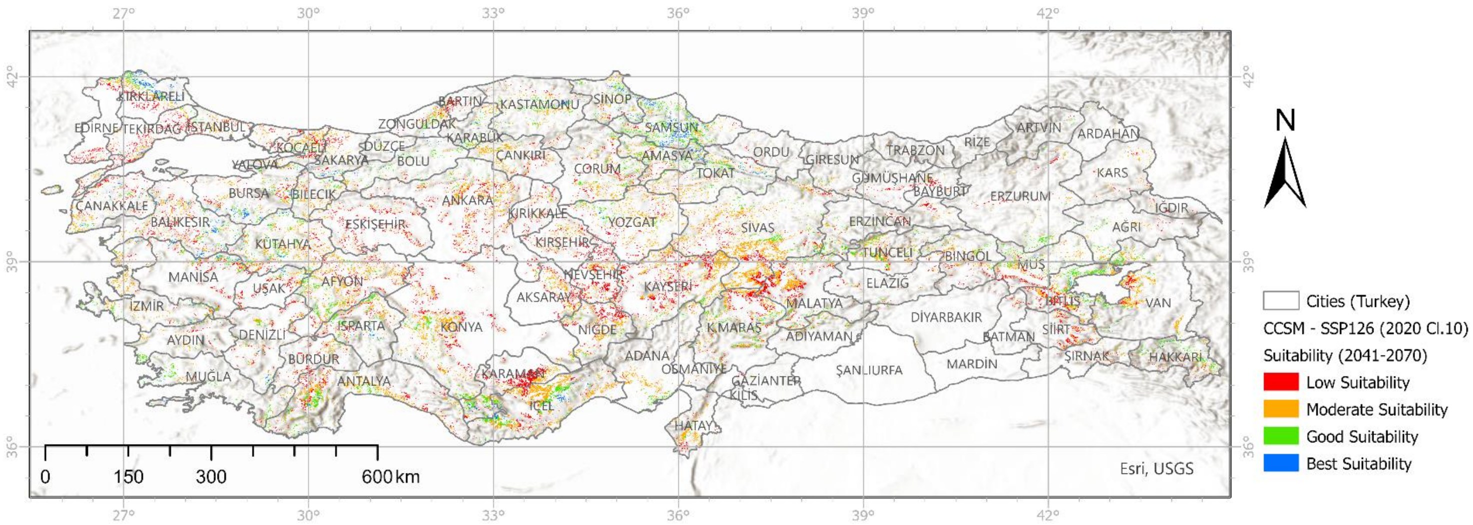

Figure 5. CCSM SSP126 results for wheat in current rainfed cropland areas (2020) (UN-LCCS Class10).

According to Figure 5, the suitability class with the highest area in today's rainfed cropland area is the Moderate suitability class. There are also regions where suitability is in the lower class. Even if these areas are used as rainfed cropland today, about 15% of these areas will be in low availability in the future.

When we look at the irrigated cropland area, the areas of the suitability classes (Figure 6) within a total area of 7,912,470 ha in Turkey are 1,080,357 ha for Low suitability, 1,680,138 ha for Moderate suitability, 618,070 ha for Good suitability and 33,991 ha for Best suitability (3,412,556 ha for all the suitability classes; 43.13% of the total irrigated cropland). Today, according to the results, medium and low suitability are foreseen as a future projection in irrigated cropland areas.

Looking at Figure 6, the future suitability of wheat in the areas used as irrigated cropland today will be medium and low suitability. In the Çukurova region of Adana, it is seen that there are areas in the Good suitability class. According to the SSP 126 projection in 2050, about 13.6% of the areas used as irrigated cropland will remain in low availability.

In the other part of the study, CCSM analyses were performed for SSP 370, a high GHG scenario. Accordingly, regardless of land use classes across the country, the suitability results are revealed in Figure 7. According to Figure 7, for SSP 370, suitability classes with Low suitability 10,672,323 ha, Moderate suitability 17,063,287 ha, Good suitability 10,003,257 ha and Best suitability 1,698,711 ha were formed. When the spatial distributions of these suitability classes are examined according to current rainfed and irrigated croplands, the results are given in Figure 8 and Figure 9.

According to Figure 8, the distributions of the suitability classes of the SSP 370 projection within current rainfed croplands (10,769,659 ha) are 1,499,020 ha for Low suitability, 2,005,437 ha for Moderate suitability, 887,267 ha for Good suitability and 152,415 ha for Best suitability (totally scored suitability area was found as 4,544,139 ha). About 14% of today's rainfed cropland will have low availability here. The area of the best suitable class decreased compared to the SSP 126. It is seen that 42.2% of the total area has a suitability score. This shows that the suitability areas for total rainfed cropland have decreased by half.

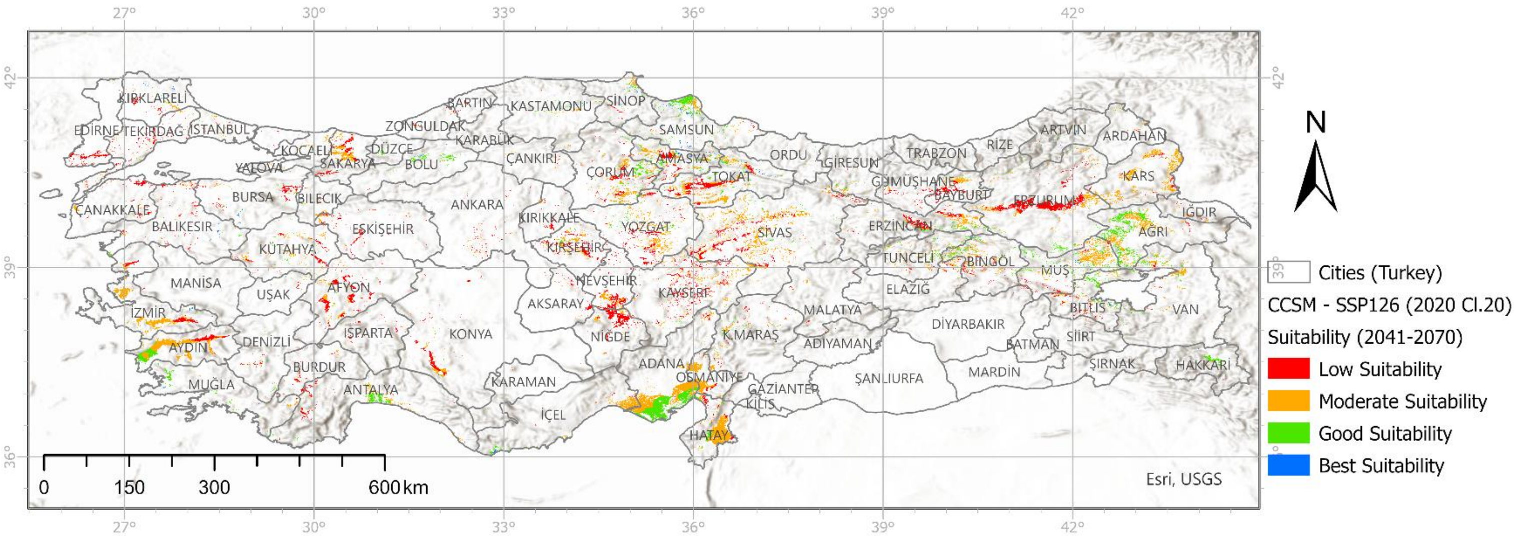

Figure 6. CCSM SSP126 results for wheat in current irrigated cropland areas (2020) (UN-LCCS Class20).

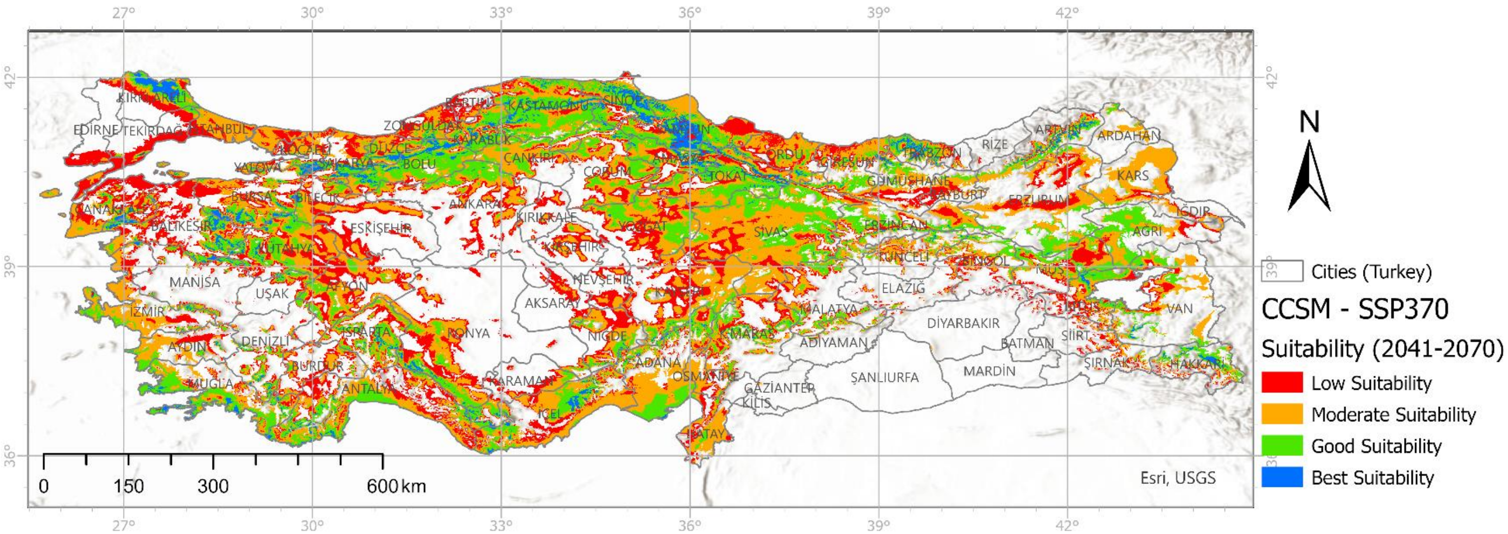

Figure 7. General CCSM results for 2050 (2041-2070 period) with analyzing of SSP370-based temperature and precipitation data.

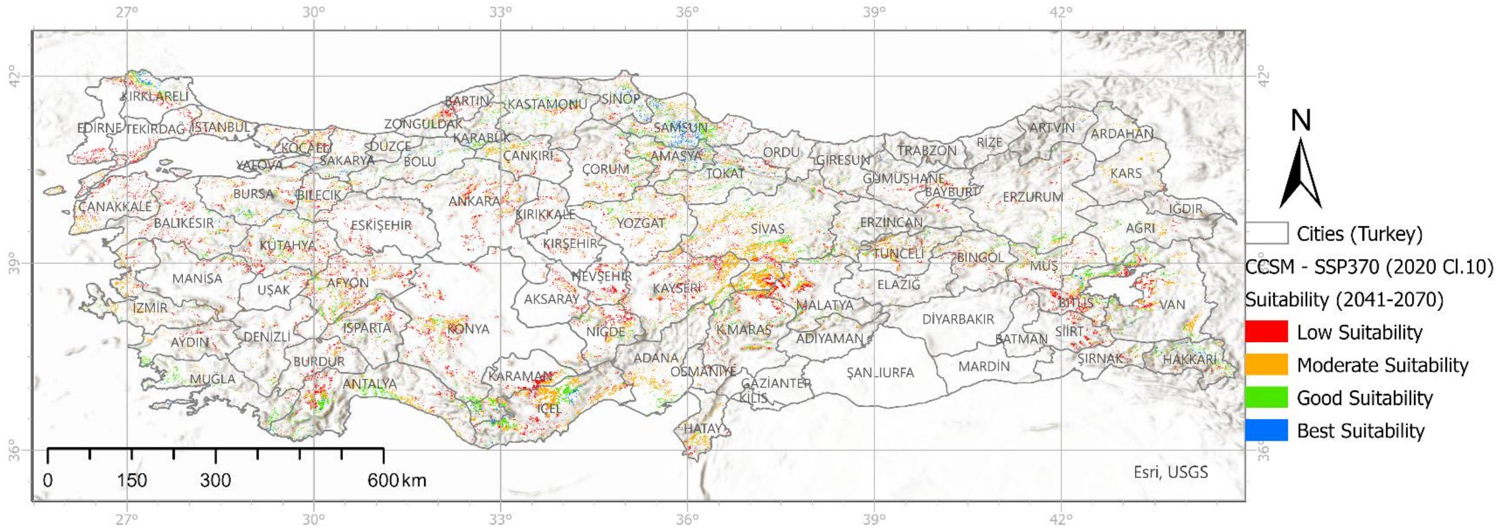

Figure 8. CCSM SSP370 results for wheat in current rainfed cropland areas (2020) (UN-LCCS Class10).

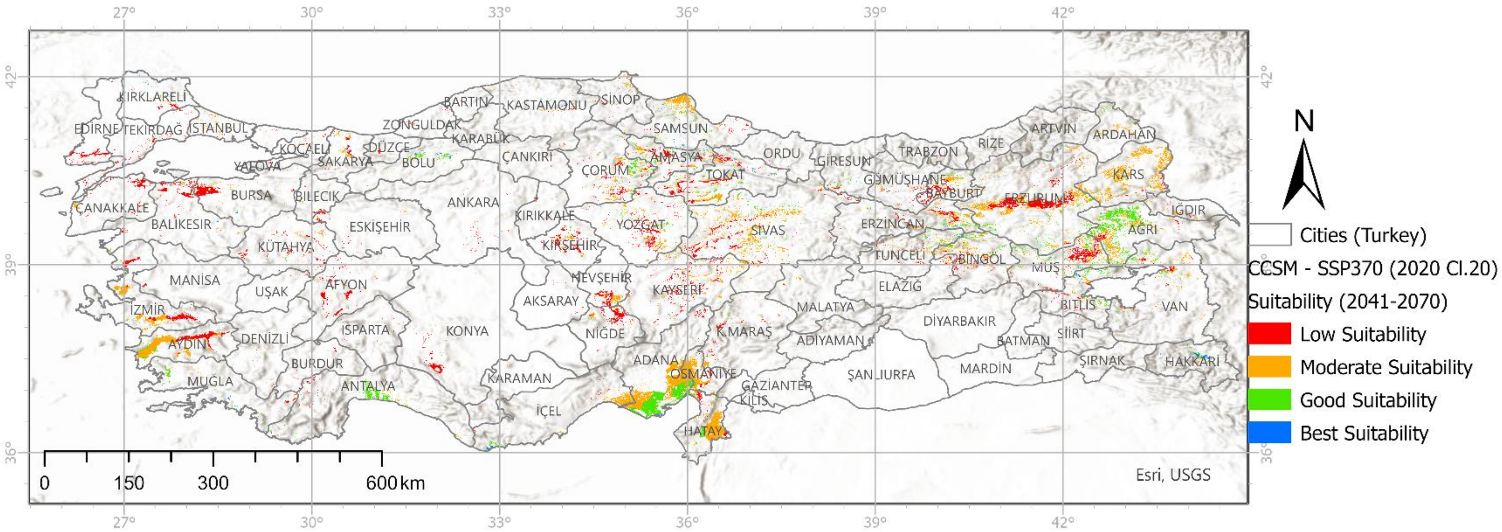

Figure 9. CCSM SSP370 results for wheat in current irrigated cropland areas (2020) (UN-LCCS Class20).

In Figure 9, the results of CCSM analyses according to SSP 370 within current irrigated cropland areas (7,912,470 ha) were 1,071,441 ha for Low suitability, 1,602,784 ha for Moderate suitability, 596,265 ha for Good suitability and 42,746 ha for Best suitability (the total scored area was found as 3,313,236 ha, the 41.9% of the total irrigated cropland area). The amount of low suitable area for today's irrigated croplands in 2050 is 13.54% of the total area. The remarkable result here is that in SSP 370, some of the areas that are Best Suitable (Aydın i.e.) and some of the Good Suitable areas (Muş i.e.) have switched to a lower suitability class when it is compared with SSP 126 (Figure 6).

In addition to all these analyses, wheat suitability was examined with the 2010 wheat harvested areas' spatial data taken from the GAEZ database. The results of this assessment are given in Figure 10 for SSP126 and Figure 11 for SSP370.

In the study, the wheat irrigated harvested area for 2010 was 10,863,596 ha. Within these areas, Low suitability was 1,477,164 ha, Moderate suitability was 2,224,382 ha, Good suitability was 828,261 ha, and Best suitability was 72,745 ha (Figure 10), according to SSP 126. In areas used for irrigated wheat harvesting in 2010, there will be a 13.6% decrease in spatial suitability, according to SSP126, in 2050. Moderate suitable areas will constitute 20.48% of the harvested area. Only 0.67% of the total harvested area will be the best suitable. As a result of the analysis, 4,602,552 ha of the 10,863,596 ha area was scored as a result of the suitability analysis. Other areas have become non-suitable.

The results of SSP370 analyses of the study again contain significant findings for irrigated wheat fields. According to the study results, Low suitability was 1,516,606 ha, Moderate suitability was 1,951,006 ha, Good suitability was 755,402 ha, and Best suitability was 39,394 ha (Figure 11). In the SSP370 results, the best suitability class was reduced by half compared to SSP126. This shows that the spatial suitability will lose a lot of area in the best suitability class according to the high emission scenario. 4,262,408 ha of the total area had a suitability score, which means almost halving the total harvested area of 10,863,596 ha. The total harvested area, in this way, in the future, will have a size in which the spatial suitability of wheat will decrease.

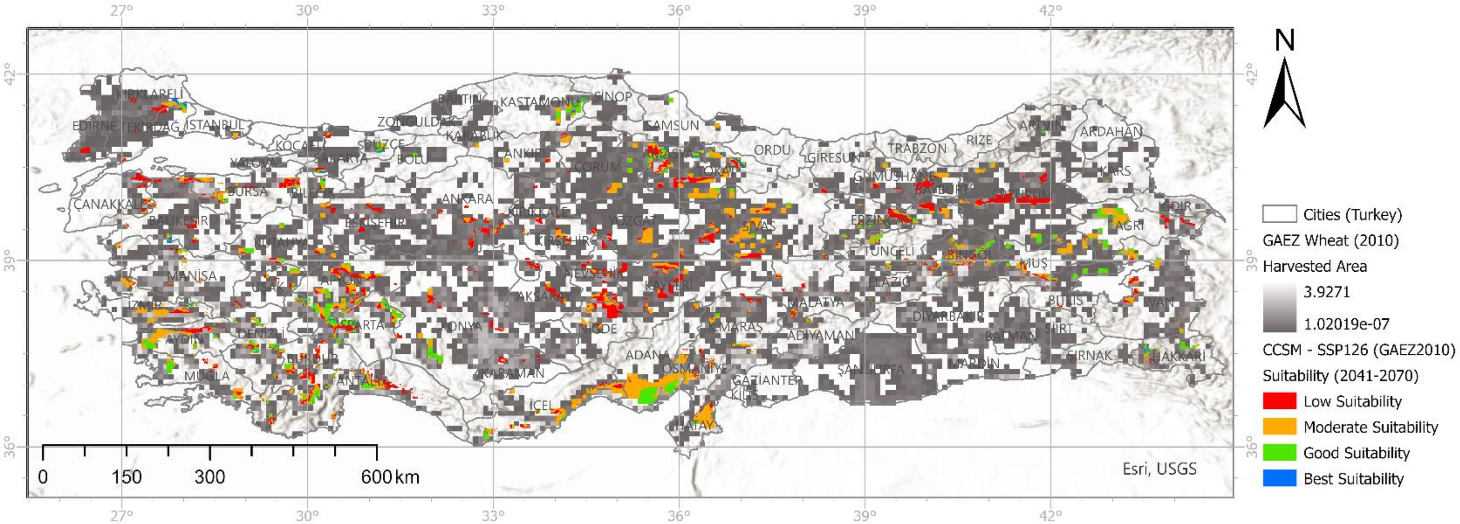

Figure 10. The SSP126-based suitability classes in the 2010 GAEZ database-presented wheat (irrigated) harvested areas.

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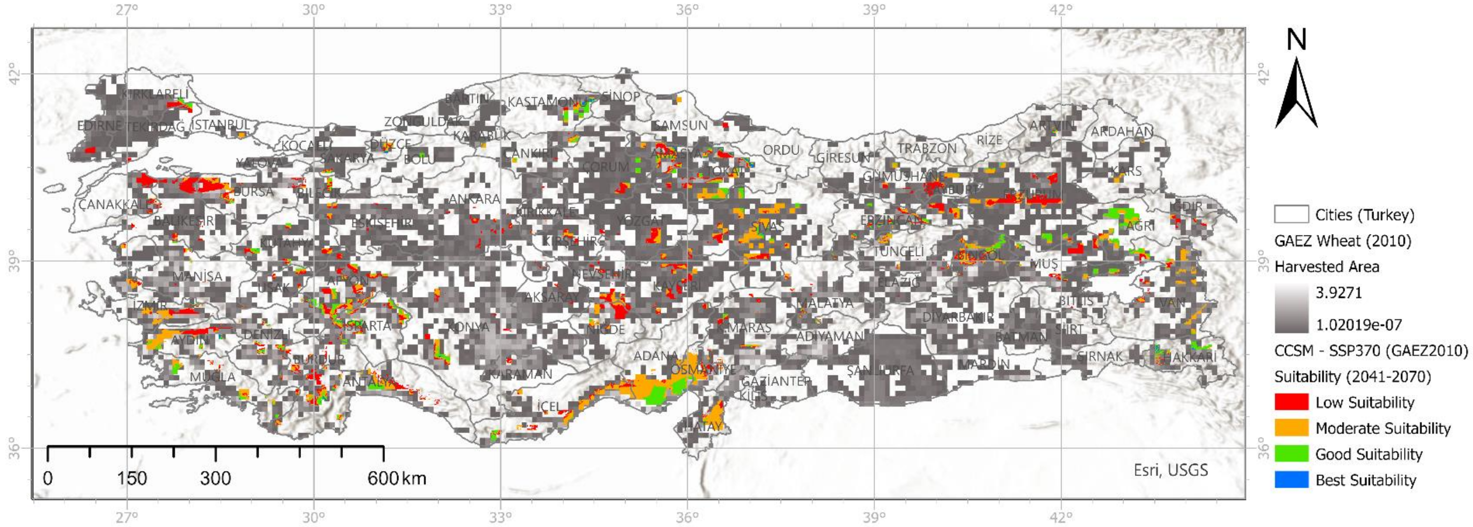

Figure 11. The SSP370-based suitability classes in the 2010 GAEZ database-presented wheat (irrigated) harvested areas.

Rainfed wheat harvested areas of GAEZ are also evaluated in the study. These areas were integrated into SSP126 and SSP370-based CCSM results, and the suitability classes were examined. The results are given in Figure 12 and Figure 13. Rainfed wheat harvested areas account for a total of 32,115,322 ha. In these areas, the suitability results based on SSP126 are given in Figure 12, and for SSP370 in Figure 13.

According to Figure 12, the suitability classes for rainfed wheat harvested areas are 5,127,271 ha for Low suitability, 7,922,157 ha for Moderate suitability, 3,184,376 ha for Good suitability and 531,977 ha for Best suitability. The total area with the suitability score was 16,765,781 ha, accounting for approximately 52.2% of the total rainfed wheat harvested area in 2010. About half of the harvested areas here have lost their suitability, while about 15.9% have had low availability.

According to Figure 13, the CCSM results according to the SSP370 scenario were 4,518,276 ha for Low suitability, 6,569,163 ha for Moderate suitability, 3,013,308 ha for Good suitability and 489,082 ha for Best suitability. The area with the suitability score accounts for about 45.43% of the total harvested area (14,589,829 ha). Therefore, 54.6% of the total harvest area has wholly lost its suitability.

As seen in this study, the spatial distribution of future suitability within the 2010 wheat harvest area was reduced by almost half for both scenarios. In regions with a spatial suitability score, the suitability is low and moderate. The areas that we call the best suitable areas and where the suitability is between 75%-100% have declined considerably compared to the total area. This situation confines wheat agriculture to a much narrower area compared to today.

Turkish agriculture is sensitive to drought, climate change (Dellal ve McCarl, 2010), and climate change affects the agricultural sector more than other sectors. Here, in cases where the prevention of climate change and the reduction of its effects are inevitable, the thing to do is for farmers to adapt to it (Karakaş, 2022). Climate change adaptation is possible by trying to predict the future of agriculture with climate models and ensuring that measures are taken now with future models.

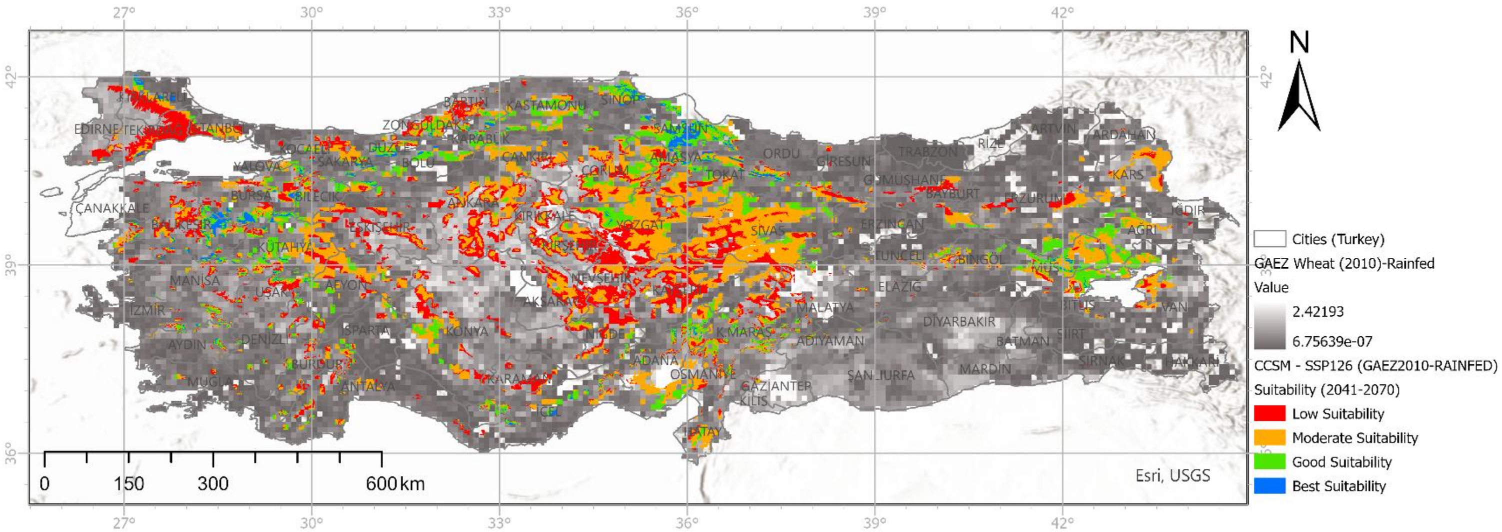

Figure 12. The SSP126-based suitability classes in the 2010 GAEZ database-presented wheat (rainfed) harvested areas.

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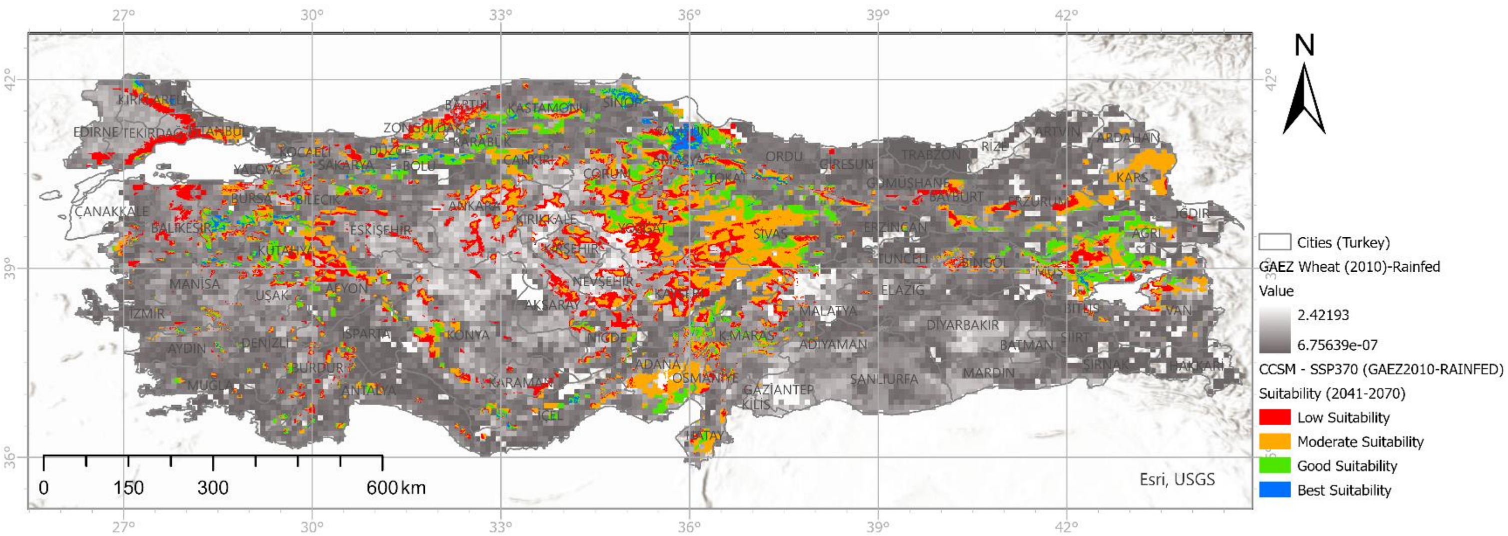

Figure 13. The SSP370-based suitability classes in the 2010 GAEZ database-presented wheat (rainfed) harvested areas.

A correct understanding of climate change by farmers is the first step to solving the climate problem. Although there are many studies on climate change adaptation, farmers generally tend to adapt to climate change and change their behaviour when they see a benefit (Asseng ve Pannell, 2013). Similarly, after making a cost-benefit calculation by acting rationally, farmers will take the necessary steps to adapt to the changing conditions if the benefit is above the cost (Karakaş, 2022). In this case, if studies are carried out on the future of crop crops with future models, farmers will be able to rationally evaluate the findings that will emerge as a result of these studies and will be willing to adapt to the foreseen changing conditions or spatial changes.

According to Karakaş (2022), determining farmer intentions is very effective in formulating agricultural policies to reduce national vulnerabilities. For example, a study conducted in Vietnam reported that the high risk of perceived climate change was more effective in helping farmers adapt. In contrast, the denial of the risk of climate change and fatalism reduced farmers' intentions to adapt. Therefore, modelling studies are critical in predicting the future and creating awareness by showing people to eliminate farmers' sense of fatalism, especially climate change.

In this study, analyses were employed on how the spatial suitability of wheat, an important agricultural product plant for our country, will change due to future temperature and precipitation parameters. This study used low and high-emission scenarios, and future spatial suitability was revealed. According to the results of the study, it was seen that the suitability scores will decrease in the regions that are seen as harvested areas today, and even the suitability will disappear in some places. This situation shows that wheat will have national vulnerabilities in the future. It is obvious that the sensitivities about wheat, an important agricultural product plant in the national sense, will affect the country's food security. Furthermore, the situation is not promising for croplands because it was predicted in the study that 58% of these areas would lose their relevance.

The effect of topography and soil on the suitability of the land for the cropping system was not taken into account in this study. Future assessments would produce more detailed and accurate results if they took them into account. Furthermore, by measuring the evapotranspiration potential and available soil water, the irrigation scheduling system (containing irrigation water amount) can be enhanced (Tuan and others, 2011).

As seen in this study, cropland suitability is not constant; fluctuations in regions and suitabilities are anticipated as the climate changes. Climate models and land resource planning tools, like the CCSM approach, give essential insights into how these changes may reallocate the land used to raise various crops and livestock and identify potential effects on productivity and yield gaps (FAO, 2021).

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Scale Issues in Design and Implementation of the Water Apportionment Accord in the Indus Basin

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Abstract

The 1991 Water Apportionment Accord (WAA) is an extraordinary example of subnational water allocation albeit not a perfect one. It established access and allocation of waters from the Indus River among the four provinces of Pakistan through finding political solutions to inter-provincial conflicts. However, the scale of its implementation remains subnational, creating several issues for the efficacy of the WAA. Using the analytical frame of scale–descale–rescale (SDR), this paper examines WAA by descaling its design and implementation at four scales: national, subnational, river basin and sub-river basin. Certain scale-driven interactions emerge between the provinces and the federal government that contribute to technical and institutional issues which, when seen from a scale lens, point to key challenges why WAA objectives are not fully achieved. A rescaling to the Indus River Basin shows an interconnected pattern of politics of scales leading to persisting conflicts that hinder planning and participation.

Keywords: Scale, Transboundary Water Governance, Water Apportionment Accord, Scale-Descale-Rescale, Indus River Basin

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1.Introduction

Problems of scale are intrinsic to environmental governance. Governance of natural resources across political jurisdictions and biophysical scales is an established discourse in the literature on human–environment relations (Cash et al. 2006). Literature on the state of global water governance presents a complex and multifaceted scenario of competing interests among multiple actors with little understanding of what characterizes best management arrangements (Groenfeldt and Schmidt, 2013; Gupta and Pahl-Wostl 2013; Lebel et al., 2005). Most policies for water governance are scale-specific in terms of jurisdictional boundaries of policy outreach and expected timeframe for achieving policy impacts. Scale-specificity, therefore, provides a logical frame for understanding the interplay of natural, societal and political processes along politically drawn jurisdictional boundaries that either overlap or completely disregard the resource boundaries. Problems of scaling-up or scaling-down environmental governance has intrigued scholars of institutional arrangements at local and global scales (Gupta, 2008; Ostrom, 1999; Young, 2002). Similarly, researchers note how scale issues are interpreted differently by different actors and the trade-offs between higher level effectiveness and lower-level accountability is key to choosing the 'right' scale of governance (Cash et al., 2006; Young, 2002; Syed et al., 2020).

In the interdisciplinary policy debates, scholars highlight the need to recognize scale disconnects (Cash et al., 2006; Ostrom, 1999). The coupled natural and human systems (CNHS) scholarship even argue for considering reciprocal relationships, nonlinearities and shifts in behaviours of different components over time and space as central to understanding the scale variations. There is no real consensus on conceptual and analytical tools for incorporating scale issues. Practical applications of scale issues within policy design and implementation remain an open discourse. Using a new analysis tool – the Scale-Descale-Rescale (SDR) – this paper unpacks the scale effects of policy design and implementation at its current scale followed by descaling to multiple levels and rescaling for cumulative outcomes at basin scale.

For Indus River Basin, scale issues have not received much attention. Historically, decision making for governing Indus River as a transboundary resource has prioritized convergence to politically drawn borders over any considerations for the overall Basin management (Syed and Choudhury, 2018). Even in prioritizing political boundaries over resource boundaries, the Indus Basin management remains largely contested between Pakistan and India with little to no involvement of Afghanistan as a Northwestern riparian or China as the riparian with geographical advantage of being at all Indus head waters (Hayat, 2020; Cilliers et al., 2013). This paper analyses the policy design and institutional arrangements of the 1991 Water Apportionment Accord (WAA) through a scale-lens. The complexity emerging from scale-driven observations show a certain disequilibrium between human-environment interactions which is compromising the long-term and sustainable management of the Basin.

2.Indus River – History, Politics and Water Sharing Arrangements

The Indus Basin stretches from the Himalayan mountains in the north and flows through the alluvial plains of Pakistan's Punjab province before entering the mostly dry plains of Sindh province and draining out into the Arabian Sea in the Indian Ocean. The Indus River Basin contains the greatest area of perennial (multi-year) glacial ice in the world at about 20,000 km^2 (Archer et al., 2010). The Indus River flow is significantly dependent on snow melt from glaciers, which accounts for approximately 41% of total runoff (Lutz et al., 2013). Glacial melt is crucial for upstream reservoirs to store and release water to downstream areas when most needed. Approximately 80% of the total discharge in the Indus River basin occurs between April and September and the historic availability shows a rapidly declining trend against pressures of a consistently rising population resulting in considerable annual variation attributed to climate fluctuations (Yong et al., 2019).

The importance of Indus River is amplified for Pakistan with an overall 65% of the country's territory situated within the Indus Basin. This disproportionate distribution of the Basin among its riparians has serious geo-political implications, given that Pakistan maintains a near existential dependence on the Indus River for its economy and food security (Adeel and Wirsing, 2017). Within Pakistan, the inter-provincial competition over Indus waters pre-dates the 1947 division of Indian Sub-continent. During the years of negotiations preceding the 1960 Indus Water Treaty with India. The inter-provincial conflicts have remained consistent and early attempts to address the dispute led to the 1945 Sindh-Punjab Agreement that allocated 75% of the main-stem Indus to Sindh and 25% to Punjab while allocating 94% of the eastern tributaries to Punjab (Mustafa, 2010). This arrangement remained in force until 1947 when the new provincial boundary of 2 Punjabs – within the borders of India and Pakistan – were formulated. The new borders meant a revision will be to revisit the earlier formula, but such revision didn't happen immediately and instead the newly formed federal government in Pakistan began allocating water on an ad hoc basis. This created a renewed sentiment among the Sindh province administrators who viewed this ad hoc practice to be favouring to Punjab. Multiple efforts were made to address the Sindh-Punjab dispute over Indus waters through a series of technical committees eventually leading to the new formula of water sharing based on 10-day seasonal system-wide adjusted allocations. This formed the basis of the Water Apportionment Accord (WAA) which was finally agreed and signed on March 21, 1991.

2.1. WAA – a contested by time-tested instrument

An overview of the past 75 years (1945 to 2020) shows a marked increase in policy and institutional development in the Indus River Basin (Figure 1) that either explicitly or implicitly addressed

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water allocation. While it took thirty years to arrive at WAA, it is seen as a step towards addressing the inter-provincial distrust by providing overarching guidelines for water allocation. The federal government and the four provinces envisioned an agreeable mechanism in the form of a new institution – the Indus River System Authority (IRSA) – to legitimize the Accord through representative participation of each province and to safeguard interests of all four provinces for equitable distribution of Indus flows. The WAA is praised for containing a politically agreed formula for distributing the available Indus water to the four provinces (Briscoe & Qamar 2006), while promoting sustainable management of the Indus River Basin through balancing agricultural and environmental needs. For the first time in the history of national scale governance planning of the Indus River Basin, the WAA not only protected existing uses of canal water in each province, but also the environmental health of the Basin by formalizing the need for escape flows below the Kotri Barrage (last diversion structure on the main-stem Indus). This provision specifically addressed the environmental flows and apportioned the 'balance of river supplies', 'flood surpluses' and 'additional supplies' from future storages (Garrick et al., 2014).

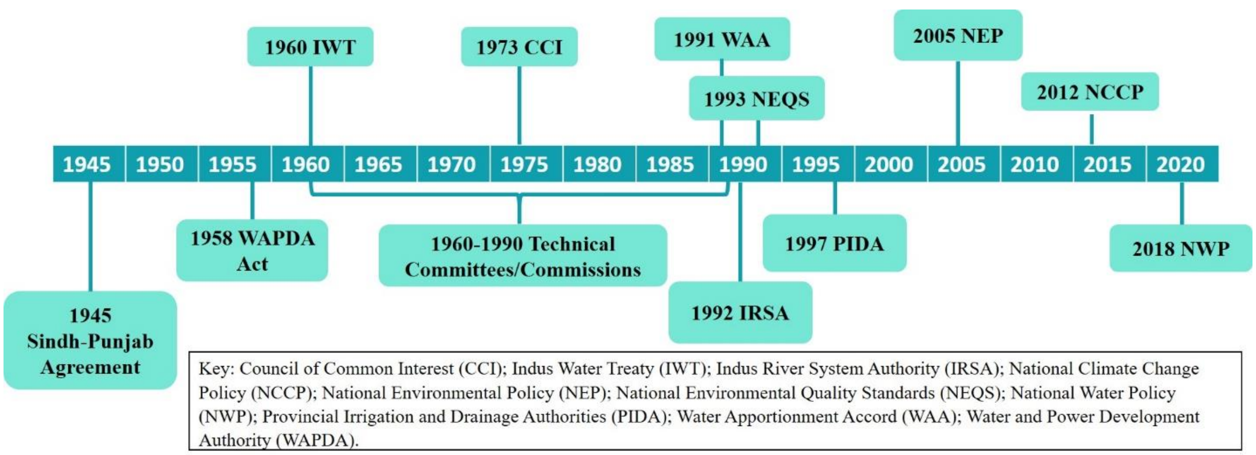

Figure 1. Key policy and institutional milestones for water distribution in Indus Basin

Between the 1960 IWT and the 1991 WAA, multiple efforts were made to resolve inter-provincial disputes. A series of technical committees were commissioned necessitated by the redefined international borders between India and Pakistan; and the provincial borders of Punjab into two Punjabs – one within Pakistan's territory and other in India's. These geopolitical changes rendered past arrangements such as the 1945 Sindh-Punjab Agreement as irrelevant, thus requiring a major shift in earlier distributive arrangements (Sattar et al. 2018; Janjua et al. 2020). During the 30 years (1960 to 1990), while the efforts to resolve inter-provincial water disputes were continuing, WAPDA was tasked to maintain water allocation on an *ad hoc* basis.

The WAA is an 8-page document, describing the water allocation and distribution formula among the four provinces of Punjab, Sindh, Northwest Frontier Province (present-day Khyber

Pakhtunkhwa (KP)), and Baluchistan. The main implementation arrangement for WAA was instituted through the Indus River System Authority (IRSA), established through an Act of Parliament in 1992. While the WAA remains a key policy instrument to date, providing platform for riparian engagement and promoting improved governance of the Indus Basin, it faces increasing critique. For instance, a key limitation of the WAA is in the persisting ambiguities of using historic patterns of use instead of robust, data-driven allocations. There are several scale issues that arise due to way WAA is interpreted and operationalized. Below is the SDR analysis of WAA to highlight the key scale issues and their implications for transboundary water governance of the Indus Basin.

3.Methodology – The Scale-Descale-Rescale Analysis Tool

Global water governance discourse acknowledges issues of competing interests with little agreement on how to incorporate these into policy action (Lebel et al. 2005; Gupta and Pahl-Wostl, 2013). Water governance policies in the Indus Basin are no exception to the complexity of competing political and socio-economic interests. What is common to water governance policies of the Indus Basin and other transboundary basins are the aspirations of implementing the principles and attributes of equitable delivery of water, participation of stakeholders in the policy process, while operating within political, social, economic and cultural constraints (Groenfeldt and Schmidt, 2013). Often sector-specific policies such as irrigated-agriculture, domestic and urban water supply, sanitation, industrial supply and environmental services, etc. are seen as the operational mechanism for incorporating principles of equity and sustainability into policy design and implementation (Pahl-Wostl et al., 2008; Syed et al., 2020). However, often sectoral policies are critiqued for their limited cross-sectoral integration (Norman et al. 2012; Norman & Bakker 2015) and lack of holistic approach to address issues that cross governance and resources boundaries (Lebel et al., 2005).

In the absence of an agreed analytical approach to operationalize scale-sensitivity assessment of water governance policies, the SDR provides an opportunity for reframing scale issues. The SDR consists of progressively unpacking the scalar effects of policies by establishing the current scale of policy in terms of its design and implementation structures (S) followed by descaling to multiple levels (up and/or down the present scale) (D), and rescaling (by integrating the aligned scales) for possible cumulative outcomes (R) (see Figure 2). The SDR essentially breaks up the given scale of policy into multiple smaller and larger units to better understand the vertical and horizontal interplay between different scales (Syed et al., 2020). In doing so, the SDR considers how the wider range of actors operating at different jurisdictional levels are interacting and influencing the decision processes. The SDR provides an analytical frame that shows the mismatch between policy impacts at multiple scales to assess the attainment of the expected impacts in a differentiated and cumulative manner. It builds on the premise that solutions to policy harmonization are seldom available at one scale and require matching multiple levels of one scale with multiple levels of another to address the spatial mismatch (Young et al., 2006).

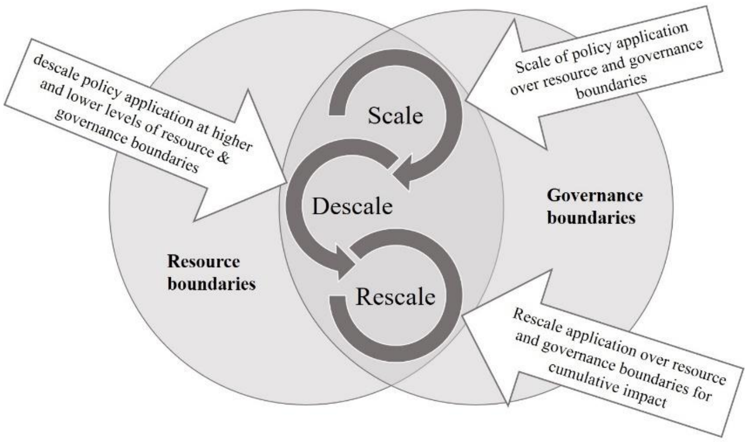

Figure 2. The Scale–Descale–Rescale analysis schematic

For transboundary water governance policies, the SDR covers both biophysical (sub-basin and basin) and governance (local, national, and multi-country) scales and recognizes the intended scope of a policy impact as its current scale. Through descaling, the SDR examines policy from a multiscale point of view, that is, the scale at which policy is designed and the scale at which it is implemented. This descaling process shows how policy design and implementation is occurring at multiple scales and the potential impact of the interplay and interactions between different scales is playing out among different actors (Moss and Newig, 2010; Termeer and Dewulf, 2014). Applying the SDR analysis to the WAA in the Indus Basin, our intention is to shed light on an aspect of WAA that has not been viewed before and that could account for some of the inadequacies of the policy design. While we remain cautious in proposing that SDR can resolve the persisting inadequacies of WAA, we are confident that looking through the scale-lens can contribute to potential realignment of politics with the CNHS perspective in governing the Indus River Basin.

4.Results from SDR Analysis of WAA

As a policy document, the WAA cannot be considered a national water sharing policy as it does not address water rights or allocative sharing for any of the special regions – namely, the northern Gilgit-Baltistan region, the north-western Federally Administered Tribal Areas bordering with Afghanistan, the north-eastern Azad Jammu and Kashmir territory under Pakistan's control, or the capital territory of Islamabad city (Arfan et al., 2020; Adeel & Wirsing, 2017). This arrangement highlights a key scale issue of political appeasement of 2 key contesting parties – the provinces of Punjab and Sindh – with a seeming attempt at generating legitimacy by involving the other 2 provinces – KP and Baluchistan.

A mismatch exists between resource availability and entitlements claimed by Punjab and Sindh. The Indus Basin Irrigation System (IBIS) is a supply-driven system and in most years, the demand exceeds supply, distributes available quantities according to the fixed rules laid out in WAA. As IBIS is almost fully operated manually, sentiments of distrust between upper and lower Indus riparians focus on quantities reported and distributed. Despite the expanse of IBIS and an estimated US$300 billion investment, the system is devoid of effective flow measurement and water accounting with no internal reregulating storage, only rudimentary control for farm-level water delivery, and unlined and leaky distribution network (Yong et al., 2019).

Geographical locations of provinces generate hydro-politics between provinces, with Sindh, being a downstream riparian, is always concerned over Punjab’s claims to water allocations (Akhtar, 2017). Such concerns are aligned with provincial governance boundaries instead of any objective analysis of resource boundaries. Repeated attempts to install a transparent and accessible measurements of canal, storage, and outflow data for use of all parties through the telemetry system have not been successful due to this inherent distrust (Bhatti et al. 2019). IRSA’s organizational structures include technical and advisory committees to provide data and technical support on the operation of reservoirs and the irrigation system; and provide transparency through representation from each of the four provinces, nominated official from the federal government and WAPDA. IRSA essentially depends upon WAPDA for all data, which impeded its decision-making on a real-tile and transparent basis (Janjua et al., 2020; Aijaz & Akhtar, 2020). Table 1 provides summary of WAA characteristics and their application at multiple scales followed by detailed SDR analysis of WAA in the Indus River Basin within Pakistan.

Table 1: Scale analysis of WAA design and implementation

Current Scale	Descale		Rescale
	National & Provincial	River & sub-river basin	
Clauses 2, 4 and 14(b) stipulate distributional principles for canal flows and balance river supplies (including floods and future storage) among four provinces	Ambiguities around interpretation of key terms such as initial conditions, shortages and surpluses remain among provinces	Each province sends seasonal estimates to IRSA that are often skewed to provincial interests instead of transparent flow data	A basin-scale automated and transparent flow measurement and reporting system is still lacking
Clauses 3, 8, 9, 10 and 11 give authority to provinces for developing irrigation and water resources projects within their share	Strategic planning for water resource management largely focused on infrastructure development and most planning is led by federal ministry of water and power through WAPDA	WAA makes provision for voluntary re-assignment of water among provinces without impeding their entitlements, there is no specific institutional mechanism established for its implementation	NWP recommends integrated approach to water resources management, but the required institutional reforms and legal framework is still not defined
Clauses 5, 7 and 12 stipulate non-irrigation uses including industrial, urban and environmental flows	Industrial and urban flows, including supplies to the city of Karachi are defined as part of provincial allocations. Maintaining environmental flows is recognized but responsibility for delivering and monitoring these flows is left vague. No agreement exits among the provinces on either quantities or institutional delivery mechanism for such flows	Agreement on quantities and mechanisms to deliver industrial, urban and environmental flows are specified. Instead, provinces are expected to use their allocations for industrial and urban supplies within their allocated shares whereas environmental flows are often neither maintained nor monitored	Basin-scale monitoring of non-irrigation uses is absent, rendering flows diverted to industrial, urban and environmental uses as unaccounted. Even in flood years, the lack of system-wide monitoring makes it difficult to ascertain true flow quantities
Clause 13 stipulates establishment of IRSA with responsibility to implement the Accord	Asset management for IBIS investments – barrage structures and headwater dams – are operated and maintained by WAPDA with little role for IRSA and provincial governments	Sub-river basins e.g. Kabul and tributaries in Baluchistan are not part of WAA provisions and respective provincial governments are expected to manage these systems	No legally assigned RBO exists for Indus River Basin. IRSA is responsible for basin-wide strategic planning but its current role remains limited to operationalizing water distribution with no

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Current Scale	Descale		Rescale
	National & Provincial	River & sub-river basin	
			capacity to function as a *de facto* RBO

4.1. Current scale of WAA implementation

The current scale of WAA implementation is assigned at the provincial governance boundary while the intended goal of WAA policy is to achieve basin-wide optimal distribution. The WAA enforces distribution of canal water flows as stipulated in the clauses 2, 4 and 14(b) of the Accord. The key formula for water distribution builds on two key principles: (i) no appreciable harm; and (ii) equitable utilization. The WAA promotes the use of prior or historic uses by each province in times of sufficient water availability, whereas in times of shortages or surpluses it promotes equitable utilization. Water entitlements are based on historic uses based on the average water withdrawal between 1977 to 1982, adjusted for ten-daily-use on pro-rata basis of seasonal allocations in the different canals.

Some ambiguities exist around interpretation of key terms used in describing the distributional principles. For example, Punjab maintains that the volumes apportioned in clause 2 are contingent upon additional storage becoming available, whereas Sindh considers clause 2 as the baseline volume and shortages and surpluses are dealt with appropriately in the Accord. Instead of considering hydraulic or economic metrices, the WAA specifies and protects existing uses of canal water for each province. It also recognizes the importance of an environmental flow allocation and provides guidance on how the balance of river supplies should be shared after administering volumetric allocation (Anwar & Bhatti, 2018). The WAA recognized importance of environmental flows to the Indus delta, but only as an issue for Sindh and not equally shared by upstream riparians, resulting in disagreement on the exact quantities or rules for maintaining environmental flows and consistent deferment to further studies.

The lack of specific allowances for environmental flow in WAA also leads to the default of unmanaged flows resulting in marginal benefits to the basin and creating other consequences such as seawater intrusion, coastal erosion, and loss of fertile land hence a major shortcoming of the WAA in adequate basin-scale management. This problem is partly due to insufficient monitoring of inflows, outflows, and canal withdrawals. The insufficient monitoring and reliable data availability continue to impede accurate water balance calculations that could potentially resolve internal fluctuations and instil greater confidence among the provinces for decision support. The lack of optimal basin-wide monitoring is compounded by issues of unaccounted losses due to system-wide leakages, theft, and lack of data from farm-use. Nearly half of the total resource in the Indus River Basin remains unaccounted due to the monitoring and information gaps. In addition, the environmental flow to the Arabian Sea is still seen as a wasteful use of water. According to some estimates, the unaccounted losses, including beneficial consumptive landscape water use and large non-consumptive losses in irrigation, are around three times the magnitude of flow to the sea, and should be a primary focus for improved water resources management in Pakistan (Yong et al., 2019; FODP, 2012). At the current scale of WAA implementation, the mechanisms adopted by provincial governments vary significantly in terms of their interpretation of WAA provisions and intra-provincial implementation arrangements for data collection and information sharing.

4.2. Descaling WAA implementation in the Indus Basin

4.2.1. Descaling to national and provincial levels

The overlapping and often unclear responsibilities and lines of administrative jurisdictions between the federal and provincial governments remain a persistent cause of confusion in water management in Pakistan. While many aspects of water resources planning are decentralized to provincial levels, issues of environmental sustainability, sediment management, major asset management (dams and barrages), interprovincial sharing, and transboundary water issues require a suitably resourced (funding and capacity) and sufficiently empowered federal institution with mechanisms for effective provincial consultation (Young et al., 2019). There is no formal River Basin Organization (RBO) for the Indus Basin. Within the WAA, IRSA could be seen as the closest form to an RBO however, it lacks the requisite capacity and legislative authority to act as one. This inability of IRSA to perform as a *de facto* RBO is also evident in the continuing distrust among the provinces. As a result, no additional storage capacity has been added to the system since 1970s, and the potential of hydropower generation as well as optimal flood management remain underachieved (Briscoe & Qamar, 2006). The WAA provision for riparians to decide and modify their allocations between system-wide and period-wise uses is the quintessential expression of provincial empowerment (Syed & Choudhury, 2018; Yong et al., 2019).

Persisting ambiguities of terminology for unanticipated scenarios, like climate change induced water variability and other externalities, limit effectiveness of WAA. Studies on historical patterns and projected trends show an overall increase in temperature and precipitation in the Basin (Rajbhandari et al., 2015; Yu et al., 2013), but this data is not used in any meaningful way to adjust allocative principles. For maintaining sufficient environmental flows there is neither an agreed mechanism for determining quantities, nor an assignment of responsibilities to enforce once quantities are determined. The lack of specificity on how these flows would be accommodated within the allocations and whether these would come "off the top" (thus reducing allocations to all provinces) or out of the allocations to Sindh (where delta is located), was left unaddressed leading to a lack of action. To date, neither the recommended quantities have been verified nor any substantive steps have been taken towards addressing the mechanism for delivering and verifying environmental flows (Yong et al. 2019; Bhatti et al., 2019; Anwar & Bhatti, 2018).

4.2.2.Descaling to rive and sub-river basins

There are increased calls for strategic basin scale planning but the mechanism to coordinate such planning is yet to be agreed. Critical areas such as joint flood planning have seen some success in improving the management of headwater dams with technical support of WAPDA, but these efforts have not delivered any comprehensive mechanism to manage assets, surface water and groundwater interactions, interprovincial water sharing, intersectoral water management, environmental sustainability, or basin-scale management of sediment and salinity and other water quality issues (Yong et al. 2019). More recently, some progress is seen where the federal government convened joint planning and stocktaking with help of external partners. For instance, the Friends of Democratic Pakistan (FODP) was established in 2008 as a donor coordination group to partner with the government and assigned a joint Water Sector Task Force to provide technical expertise and policy advice.

While the World Meteorological Organization (WMO) recommends one gauge per 250 km^2, in the Upper Indus, just one gauge covers nearly 5,000 km^2 (UNDP 2017). Other recommendations include installing at least 75 Automated Weather Stations (AWS) and 35 hydrological monitoring stations across the Upper Indus Basin to accurately account for seasonal variations and correct the data discrepancies from valley floor monitoring stations. A key argument against calls for reviewing the WAA is that a unanimous agreement is required from all concerned parties, making it extremely difficult to negotiate any changes to the existing procedures. It took several decades to arrive at the decision for ensuring supplies to the twin cities of Rawalpindi and Islamabad (Anwar & Bhatti 2018). As the systemwide water demands continue to grow, the demand to revisit and renew existing water allocation principles requires a concerted shift in the institutional adjustments in the current federal and provincial mechanisms. Recently, some provinces have voiced their support for introducing new mechanisms in the existing provisions of the WAA to operationalize clauses 14(d) and 14(e) related to voluntary re-assignment of water among provinces without impeding their entitlements. The provincial government of Khyber Pakhtunkhwa (KP) made a public statement welcoming the discussion to establish an agreed mechanism for development of the flexible, voluntary arrangements which are needed in all arid environments. While Baluchistan refrained from any deliberate statements, both Sindh and Punjab were quick to oppose the idea.

4.3.Rescaling to Indus Basin

The WAA is lauded for being a significant achievement in addressing inter-provincial water disputes in Pakistan. This praise is well-placed especially since similar policy instruments do not exist in other parts of the Indus Basin located in India or other riparian countries. Despites its deficiencies, WAA remains a key step towards basin-wide management of the Indus River. Having survived nearly 30 years since its formulation, the WAA, as a policy instruments, has established its resilience. While there are multiple views on reviewing, revising and even doing away with the WAA, its usefulness remains uncontested. At a basin-scale, WAA contains the potential for becoming more adaptive to the changed realities of the Indus Basin and it this aspect that has merit for discussion rather than a drastic revision. Similarly, the institutional arrangements for WAA need to remain flexible to address the contingent needs of the IBIS as they arise, for instance, issues like adapting to climate change, relying more on virtual waters, and using conservation technologies more effectively to gain water efficiency and improve water quality (Janjua et al., 2020).
The mutual benefit creation could be the single most significant virtue of the WAA as opposed to current practice of contestation that creates winners and losers among the provinces resulting in *status quo* of provincial disputes. Three key areas are important to a scale-sensitive WAA as follows.

4.3.1. Balancing institutional arrangements between province and federation

The growing challenges of climate change, and the increasing evidence of environmentally unsuitable water management with significant negative consequences, Pakistan remains vulnerable to increased water scarcity in the absence of strategic planning for the entire Indus Basin. The long-term environmentally sustainable economic development of the Indus River Basin, the IBIS, and the sub-river basins such as the Kabul and sub-river basins in Baluchistan, a basin-wide joint mechanism is needed with clear institutional and technical responsibilities for evidence-based planning. The 2018 National Water Policy (NWP) recommends a comprehensive and integrated approach to water resources management, but the required institutional reforms and legal framework is yet to be put in place.
As part of setting up the institutional arrangements referred in 2018 NWP, priority must be assigned to updating the current institutional setup of interactions limited between IRSA, WAPDA, and the provincial irrigation departments, to include missing stakeholders. Specifically, this will mean creating an institutional mechanism to address water needs of regions not

originally included in WAA, including Gilgit-Baltistan, Federally Administered Tribal Areas, Pakistan-controlled Kashmir territory, and Islamabad, the capital city of Pakistan.

At national and provincial scale, the IRSA presents a unique opportunity for strengthening the existing institutional mechanism. Even though IRSA's institutional structure doesn't accord it the legal status of an RBO, it still operates as an RBO. For instance, IRSA holds the mandate for coordinating information sharing and data verification as well as the task to carry out strategic basin-scale planning. At present, IRSA performances primarily the tasks associated with operationalizing water distribution with no capacity to function as a de facto RBO. Since IRSA is a representative institution, it already enjoys the political acceptance by the four provinces and formally assigning IRSA as an RBO for the Indus River Basin could be linked with the calls for its institutional strengthening.

At the basin-scale, while the 1960 IWT brought a formal river-sharing agreement between two riparian states, India's provinces, especially the Punjab, Haryana, and Rajasthan, continue to fight over their rightful share of the waters of the Ravi, Beas, and Sutlej rivers. Inter-provincial disputes are not unique to Pakistan part of the Indus. Very little is accomplished in terms of having a set policy instrument at the basin-scale with WAA being shining light that is currently focused on one part of the basin – albeit being the larger portion – while the remainder part of Indus, especially located between several Indian States could learn from the experience of WAA to formulate a similar instrument and then aggregating it to combine the WAA with Indian equivalent of it (if there ever would be one), to a truly basin-scale instrument, creating an instrument of mutual gains for both India and Pakistan.

4.3.2. Harmonized flow measurement

A key loophole in WAA design is presented by the method used for estimating seasonal water availability in the canal network. In the absence of an automated, transparent, and unified system throughout the IBIS network, manual calculations are carried out at select diversion points. This leads unreliable data prone to mistakes as each provincial irrigation department provides reports of flow measurements for the barrages and the heads of the canals that are located within the provincial boundaries. Most seasonal estimates are derived from correlations with prior irrigation season deliveries. Each province is responsible for providing its own estimates while IRSA adapts these estimates as the season progresses. The provincial estimated are often considered skewed if not overtly exaggerated to align with provincial interests. This practice severely undermines IRSA's authority especially since IRSA maintains no in-house technical capability to establish its own estimates or verify data provided by provincial irrigation departments (Young et al., 2019). A fully functional system-wide telemetry system has not been made operational since the WAA came into force.

In recent years, some positive development has been made although not across the entire IBIS. For instance, since 2007, Punjab is publishing on its provincial irrigation department's website, the data on flow measurements at the head of each canal (and down the canal). Updates are posted online every two weeks. More recently, Punjab has also started publishing the discharge measurements at the head of each canal with daily updates. This has been recognized as a significant step towards resolving trust deficit among provinces however other provinces are yet to follow the example of Punjab. If each province adopts similar practice, the measurements made by each province could not be verified but will also effectively build trust. If IRSA is to be transformed into an RBO for the Indus basin, its role could also be strengthened by assigning it the responsibility to verify provincial information however technical capacity for IRSA remains a key issue for it to play this role effectively.

Some recent efforts have been made towards addressing the data gap in governance of Indus and the federal government has renewed its plan as part of the 2018 NWP implementation. However, it is important to incorporate lessons from previous experiences of installing the telemetry system which included several concerns on data quality, measuring structures in the form of flumes or broad created weirs, and introducing modern technologies for direct measurements. At the same time, attention to the data delivery and information sharing mechanisms must be included in the automation planning with careful measures to limit possibilities of human error in processes as well as quick and transparent means for making data available to public and policy makers.

4.3.3.Politics of scale and achieving mutual benefits

While the WAA makes provision for voluntary re-assignment of water among provinces without impeding their entitlements, there is no specific institutional mechanism established for implementing this. From the perspectives of equity, efficiency and conflict reduction, there is a strong case for introducing mechanisms to facilitate a voluntary re-assignment of water among users. Provinces could be better off if there were mechanisms whereby some entitlements could be temporarily transferred from one province to another. In some cases, this is because provinces do not have the infrastructure needed to use their allocations and have concerns that non-use may eventually lead to questions about its rights to that water. Their water is currently being used by others, and they would like to be compensated for this. In other cases, such a voluntary transfer (in exchange for payment) would benefit both buyers and sellers and result in water moving from lower-value to higher-value uses. In other countries this mechanism has been vital in maximizing output, minimizing conflict and providing resilience in times of drought.

Accurate and reliable information, equally accessible to all parties, independently verifiable, improve water accounting in the Indus Basin (which includes but is not limited to flow measurement at key installations). A clear set of annual or biannual water accounts like those released by other river basin authorities would go some way to reducing mistrust between stakeholders. A slightly more challenging issue, but again within the framework of the Accord, would be to improve the Operating Rules and ensure that these are well documented. For all the shortcomings of the Accord, it would be prudent to work within the Accord before embarking upon any revisions to the Accord itself. At the same time, improving the stakeholder engagement mechanism in the WAA would lead to greater legitimacy of the Accord by including additional parties and civil society groups in the consultative and information sharing processes of the Accord. However, such steps will require IRSA to step up its institutional role beyond the current water distributional tasks and take on the role of an RBO that promotes inclusive development, ecosystem services, and adaptive management. Such a shift will also require a change in the current mindset prevalent among the provincial policymakers to consider their provincial interests as part of the basin-scale issues.

An important outcome of building a mutually beneficial proposition for the provinces would be in the form of joint planning for augmenting current storage capacity at a basin scale. According to some studies, Pakistan storage capacity is well below the internationally recommended levels – 30-day supply compared to 1000-day supplies (FODP, 2012; ADB, 2013). The stalemate over any significant progress on increasing storage capacity primarily results from lack of trust among the provincial governments. Confidence building measures among the provinces in the form of independent, third-party technical studies should be considered as recommended in the NWP implementation framework that includes setting objectives at institutional, legal, and operational levels.

5. Discussion and Policy Implications

In considering the future course of action for governing the Indus River Basin, three specific areas are of key importance as follows.

6. Changes in the Indus River Basin

The water balance within the Indus River Basin is evidently changing due to climate change, river morphology and increased pressures of population growth and economic development. It is already becoming clearer that some of the original assumption under which WAA was designed and its implementation conducted over the past 30 years, will require to adapt to the new realities. Opening a positive dialogue for revising the WAA will not be easy despite a common understanding that systemwide demand for water is growing along with increase in climate variability in system flows and a flexible approach is needed to address the growing vulnerability of the IBIS and plan for Pakistan's water security. Politics of inter-provincial interactions will make these realities difficult to ignore and a pronounced engagement will be needed from other federal agencies as well as a broader segment of stakeholders previously not engaged in WAA formulation. Any deliberations will also need to articulate improved institutional and legal framework including implementation arrangements at federal and provincial scales as well as involvement of water users and broader communities. Upgrading IRSA into an RBO would need to figure among the key institutional reforms and generating strong political support would be the first step towards this process.

7. Balancing irrigation and non-irrigation use

The WAA was an instrument to resolve inter-provincial disputes over water sharing and while it acknowledged industrial, urban and environmental needs to be addressed from Indus waters, it didn't establish a robust mechanism for the non-irrigation uses. At the time of WAA formulation, the non-irrigation demands were relatively small and in many instances were almost entirely met by groundwater abstractions. With the economic development away from being purely agricultural reliant to non-farm manufacturing and service industries compounded by the population growth, competition for water has increased while options for supply augmentation have remained limited. Model-based assessments indicate that increased flexibility in surface water allocation within provinces—both within agriculture and between sectors—can increase agricultural profits and improve outcomes for domestic, industrial, and environmental water users (Yang et al., 2014). Ensuring reliable supplies for both irrigated agriculture and non-irrigation uses, especially during periods of drought and scarcity will require system-wide adaptations such as promoting high efficiency irrigation technologies, crop diversification towards high value produce, and improved practices for water conservation.

8. Modernizing institutional and legislative structure

Incorporating responsive mechanisms for inter-sectoral water allocation could be best achieved if institutional reforms are made at multiple scales. For instance, the provincial irrigation departments, together with the canal command area water boards and farmers organizations will need to work together through clearly defined arrangements for collective planning and management of water resources. Although constitutionally, water is largely a provincial matter in Pakistan, relevant policies, institutions, and legal provisions are distributed across the national and provincial levels. National institutions coexist with, and sometimes overlap with, provincial institutions, and the legal framework for each province includes its own laws and regulations overlain by relevant national provisions (Young et al., 2019). As part of modernizing institutional and legislative structures to govern the Indus River Basin, actions will be required at multiple scales for effective governance at basin scale. For instance, at basin scale, assigning IRSA the role of an RBO would mean transforming IRSA into an adaptive and learning institution with capacity to cope with variabilities and uncertainties associated with climate change and other externalities. As and RBO, IRSA will also require stronger mechanisms for consultations with and involvement of various actors, for generating and disseminating knowledge.

9. Conclusions

There is a growing recognition that basin-wide management and transboundary water governance of the Indus River cannot be achieved by WAA alone. Findings from the SDR analysis highlight that WAA implementation will remain limited due to the mismatch of actions being taken at different scales. Conflicts over Indus waters predate the IWT and while WAA broke new grounds by arriving at an expression of consensus policy, its implementation arrangements and lack of specific mechanisms for generating, sharing, and validating information remains weak leaving much to be desired. While through WAA, all provinces are increasingly working together, absence of other stakeholders has become more apparent with shifting trends in the country and in Indus River. At each governance level – national/federal, provincial/subnational, basin and sub-river basin – SDR analysis provides insights into the details of what is working well and what remains to be addressed, to achieve effective transboundary implementation of the Indus River Basin.

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