The present work was submitted to the Engineering Faculty

Identification of Potential Location of Pond Sites for Irrigating Agriculture and Forestry Land Based on Watershed Analysis Using GIS

Bachelor Thesis

Submitted by

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Nalaikh, Ulaanbaatar

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Statutory Declaration

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Identification of Potential Location of Pond Sites for Irrigating Agriculture and Forestry Land Based on Watershed Analysis Using GIS

I did not use any sources other than those stated. In case that the work is additionally submitted on a data medium, I declare that the written and the electronic form are completely identical. The work was not submitted in the same or similar form to any examination authority.

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Abstract

The identification of potential locations for pond sites plays a crucial role in sustainable water resource management for irrigated agriculture and forestry land. This study focuses on utilizing watershed analysis techniques in combination with Geographic Information Systems (GIS) to identify suitable locations for constructing ponds. The objectives of the study are to assess water availability, identify suitable sites, and recommend areas for afforestation that uses near water sources. In this study, Watershed and Stream Network Analysis were done in the Kherlen Soum area in Khentii Province. Also using the ArcGIS program some additional analyses such as hillshade, slope, and basin delineation. Using the stream network analysis with the cadastral map of Kherlen soum and setting 3 criteria we determined the potential pond locations. After determining the potential pond sites we recommended 4 types of areas for the afforestation of the national movement of “Billion Tree” in Kherlen Soum. Recommended 4 types of areas are Unirrigated Self-Growing Tree Areas, Irrigated Growing Tree Areas, Forestation areas of Old Farmlands, and Kherlen River Irrigated areas. Using the Mongolian National Standard for Environment and Re-vegetation of destroyed land we estimated the standard for planting in one hectare as 722 units of trees and bushes. It will be a reserve forestation area for approximately 80 million units of trees and bushes by our rough calculation.

Keywords: Stream Network, Trees and Bushes, Water source, Pond location, Farmland, Geographical Information System (GIS), Kherlen soum, Irrigation, Forestation

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Lastly, I am extremely grateful for my family who always supported me and encouraged me throughout my life.

1 Introduction

Water is a precious resource provided by nature that is essential for the survival and well-being of all living organisms. It is widely recognized that the quality and quantity of water are critical factors that impact the growth and progress of communities. Various natural and human-related factors contribute to the condition of water sources, affecting both its quality and availability. The greater part of Kherlen soum is characterized as an arid and semi-arid region. Groundwater serves as the primary water source in many regions, particularly in arid and semi-arid areas (ASARs), and its availability greatly impacts economic and social development. Effective water resource management plans need to consider the conservation and appropriate utilization of soil as a natural resource. However, in recent years, ASARs have faced intensified pressure on water resources due to climate change, escalating water demands for urban and agricultural purposes, and the adverse effects of deforestation and reduced rainfall on infiltration rates. This has significant implications for both urban and rural communities, as water is a vital resource for daily sustenance and the challenges associated with increasing urbanization further exacerbate the situation (1). The World Water Council report indicates that the worldwide water crisis stems primarily from insufficient management practices rather than a scarcity of water itself. Inadequate water management is further compounded by the complexities presented by environmental factors and population dynamics. To tackle this crisis, the report emphasizes the utmost importance of effective water management. This entails the implementation of sustainable and efficient approaches for water allocation, distribution, and utilization. The challenges posed by environmental aspects, including climate change, add further complexity to the task of managing water resources. Therefore, addressing the global water crisis necessitates comprehensive strategies that account for the interplay between water management, environmental considerations, and the evolving needs of a growing population (2). According to the estimation by the United Nations Environment Program, it is projected that in the coming years, over two billion individuals could potentially experience conditions of water scarcity or limited access to water resources (3). Arid and semi-arid regions (ASARs), which account for approximately 35% of the Earth's land area, face persistent challenges related to water scarcity. These challenges adversely impact various aspects such as availability of clean drinking water and the practice of agriculture and horticulture. ASARs span approximately 50 million square kilometers in total (4). In arid regions, residents have developed diverse approaches to enhance water availability for their agricultural activities and livestock. These methods include the construction of dams, pans, percolation tanks, and ponds to collect and store water. Interestingly, archaeological evidence suggests that water collection practices have been utilized since ancient times, dating back approximately 9000 years ago. These practices have been observed in various countries across the globe, including Jordan, Palestine, Syria, Tunisia, and Iraq (5). The proper identification and evaluation of pond sites play a vital role in effective water management and environmental monitoring. It is important to comprehend the distinct characteristics of pond sites in terms of their physical, chemical, and biological attributes. This understanding is crucial in assessing the overall health, productivity, and environmental impact of these sites. In the realm of hydrogeological science, remote sensing and Geographical Information System (GIS) have emerged as prominent tools that aid in the assessment, monitoring, and conservation of various water resources. GIS technology offers effective solutions for managing extensive and intricate databases with efficiency. In recent times, the growing utilization of satellite remote sensing data has simplified the process of delineating the spatial arrangement of various water potential categories. This is achieved by considering factors such as geomorphology and related parameters.

As we know the President of Mongolia addressed on General Comment of the 76th Session of the UN General Assembly on September 22, 2021, he stated that to fight against the climate change, Mongolia will plant a billion trees by 2030. For that reason, Khentii Province's Kherlen soum was assigned to 40 million trees to grow and it's 75 percent or 30 million trees to be maintained by 2030.

This thesis aims to explore the state of the art in topic identification of pond sites using various remote sensing techniques, including aerial photography and satellite imagery, along with and data analysis.

The results of this study will provide valuable insights into the current state of the art in pond site identification and contribute to the local ongoing projects in Kherlen soum and improve the monitoring and management of these important environmental ecosystems around it.

1.1 Objectives of the study

The thesis aims to identify potential pond locations and recommend areas for new afforestation area using Watershed analysis with Stream Network analysis in Kherlen soum, Chinggis city. The main objectives are the followings:

- Assessing Water Availability: To assess the water resources within a watershed and ascertain the amount and accessibility of water for irrigation needs, an evaluation is conducted. This evaluation entails the examination of factors including precipitation, runoff, groundwater, and streamflow behavior. By analyzing these elements, an understanding is gained regarding the quantity and availability of water specifically for irrigation purposes.

- Identifying Suitable Locations: The task is to pinpoint prospective sites within the watershed that are appropriate for establishing ponds to facilitate water harvesting. This involves considering a range of criteria, including topography, soil composition, land usage, proximity to water sources, and the capacity for water storage. By evaluating these factors, suitable locations for constructing ponds can be identified.

- Integrating GIS and Remote Sensing: Leverage the capabilities of GIS and remote sensing methodologies to collect and evaluate spatial data associated with the watershed. This includes obtaining and analyzing topographic maps, satellite imagery, land use maps, and hydrological data. By integrating these diverse data sources, holistic and precise representations of the study area can be generated.

- Applying Watershed Analysis: Perform a comprehensive analysis of the watershed to gain insights into its hydrological processes, flow dynamics, and interconnections. This analysis aids in the identification of specific regions where the construction of ponds can have a substantial influence on the availability and distribution of water resources.

- Providing Recommended Area for Agriculture and Afforestation: Identify potential locations for afforestation or agricultural activities and assess their suitability for implementing various projects within the study area. Ensure that the recommended areas are sufficient to accommodate the proposed projects. Based on the findings of the study, offer recommendations and guidelines for the successful implementation of pond projects in the future.

1.2 Study Area

The average annual temperature of 2022 in Mongolia is 0.8°C, which is 1.43°C warmer than the average of 1961-1990, when climate change was relatively weak, and the 16th warmest year since 1940.

Regionally, it is +6.0 to +10.0°C in the south of Gobi region, Altai Upper Gobi region, +2.0 to +5.8°C in the steppe regions and around Great Lakes depression, Khuvsgul high mountains, Khangai mountain range, and Darkhad depression area. -4.0 to -8.0°C, and in other areas -2.0 to +2.0°C.

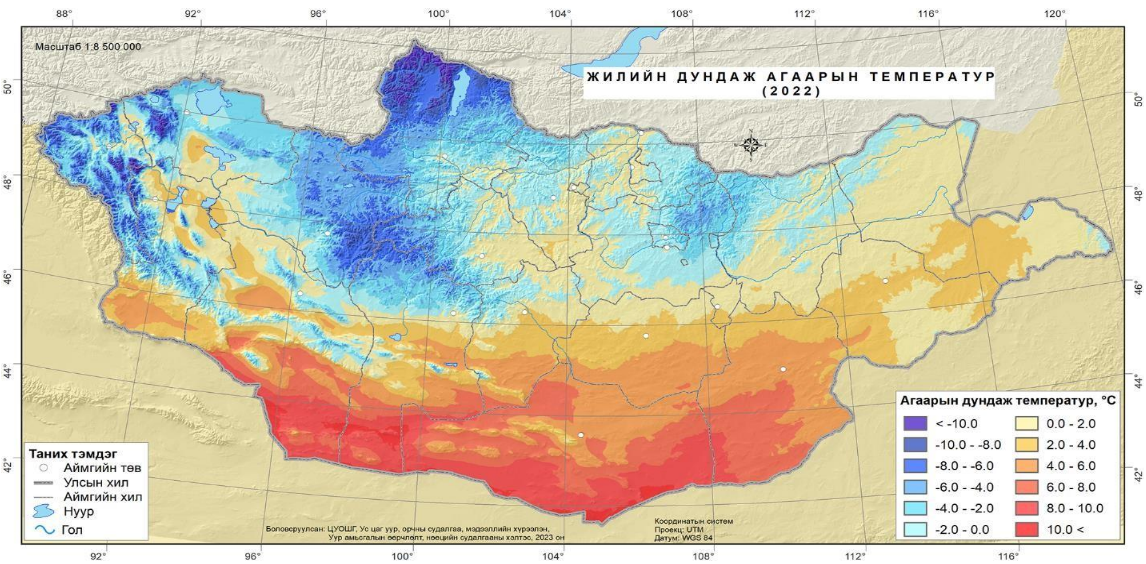


Figure 1. Spatial distribution of average air temperature in 2022

The average annual rainfall of 2022 for Mongolia was 200.6 mm, which was the 19th year with the lowest rainfall since 1940. Considering the spatial distribution of the total annual precipitation (Figure 2), it is 390-517.8 mm in the high mountains of Khuvsgul, Khentii mountain range, Khangai mountain range, near the basin of Onon Balj river, Khuvsguli Tarialan, Binder of Khentii, and Bayan-Uul sumd of Dornod. 100.0-192.8 mm in Gobi region, and 10.0-21.6 mm in

Altai Ovar Gobi, Toroor and Ehi main areas. The highest value of total annual precipitation was 517.8 mm in Dadal sum of Khentii province.

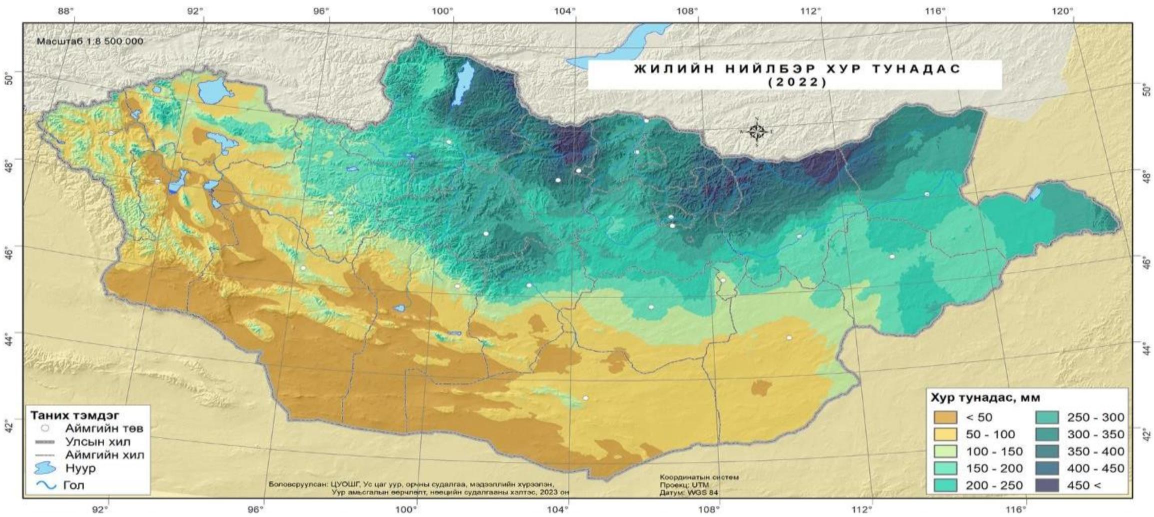


Figure 2. Spatial distribution of total annual precipitation in 2022

m above sea level in the plain area of the Kherlen River, which originates from the Khenti mountain range. Kherlen soum belongs to the steppe zone in terms of climate, with hot summers and cold winters with an average precipitation of up to 103 mm. The coldest month of the year is January and the air temperature reaches -32.2℃ at the highest, the warmest months is July and the temperature fluctuates between 25.5℃- 32℃, the average annual temperature is 2-4 ℃. It belongs to the field brown soil zone. Rainfall and wind play a major role in the formation and development of soil cover in this region. The wind has a great effect on breaking the soil by blowing away the top part of the soil by activating the soil air exchange. During periods of abundant rainfall, vegetation cover will be greatly improved, reducing soil erosion. Brown and gray soils are predominant in the flat highlands and are covered in some places by gravel and granite. Light gray clayey and marly soils are abundant in hollows and depressions.

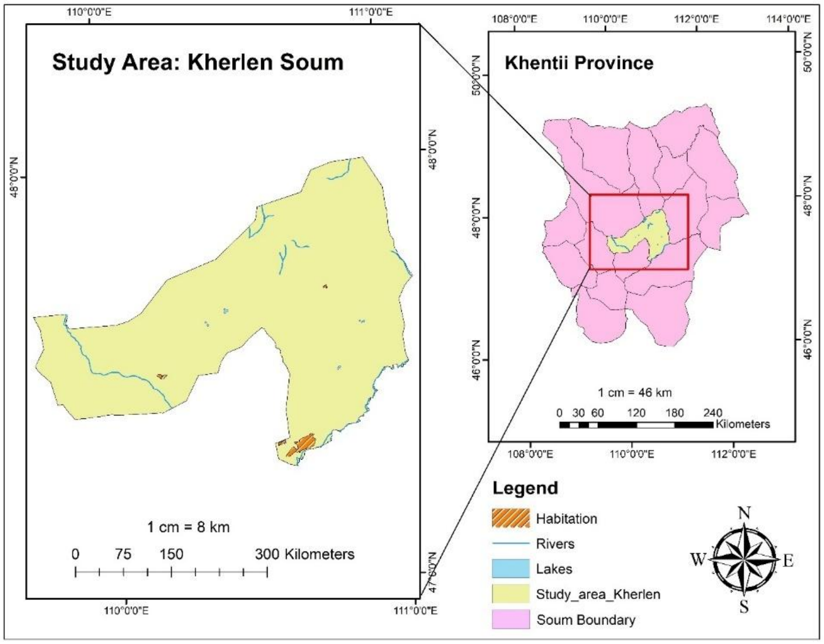


Figure 3. Study area map of Kherlen soum, Khentii province

As we can see from figure 4, Khentii soum's most of the land is occupied by plains or steppe which means it is very suitable for agriculture and forestry land use. If we look back to the history of Kherlen Soum's land use during in the 1980s in socialism there were many state-owned farmlands, but after the democratic revolution, these farmlands were allocated to individuals and most of them now not used for any purposes.

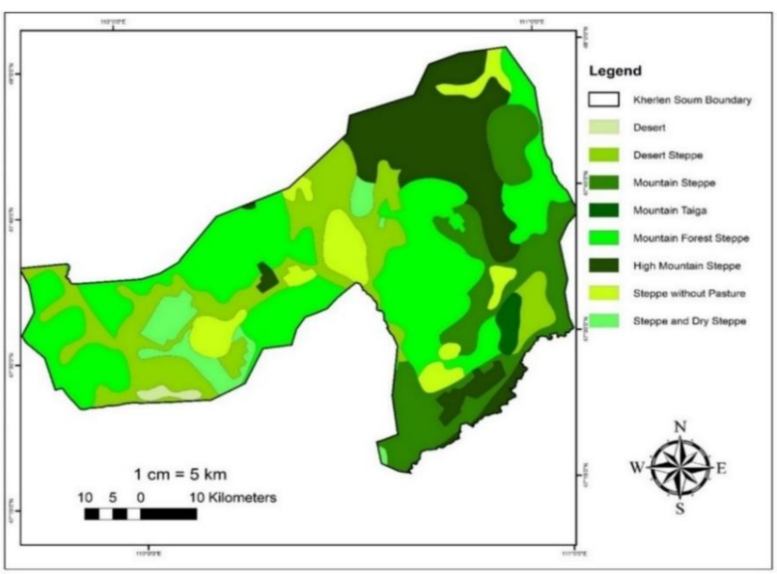


Figure 4. Soil structure map of Kherlen Soum, Khentii province

2 State of the art

A reservoir, as defined by the U.S. Geological Survey, is a body of water, either natural or artificial, that is used for storing, controlling, and regulating water (6). Differentiating between natural and man-made reservoirs can pose challenges due to the common practice of modifying natural depressions or waterways during reservoir construction. For instance, a naturally occurring low area that occasionally fills with water would not qualify as a reservoir unless it was altered to regulate water flow. Likewise, a naturally formed lake can be classified as a reservoir if it has undergone modifications such as dredging or pumping. Essentially, any body of water that exhibits indications of being manipulated for water management objectives can be categorized as a reservoir.

On-stream and off-stream reservoirs, along with natural waterbodies, possess unique characteristics. Natural waterbodies typically exhibit a rounded or less defined shape and are encompassed by wetlands and diverse vegetation types, including shoreline and emergent plants. This vegetation creates a gradual transition from water to land, facilitating a consistent water level by capturing rainfall in shallow sections. The deepest area of a natural waterbody is typically found at its center, while the outflow region tends to be shallower. Moreover, natural waterbodies often have smaller drainage basins situated at the origins of streams or rivers. (7).

Small off-stream reservoirs, such as retention and farm ponds, typically rely on precipitation or groundwater as their water source and often have a rectangular or square shape resulting from dredging activities. These reservoirs commonly lack shoreline vegetation, making them susceptible to direct rainfall impact, leading to the accumulation of elevated nutrient and sediment levels. Additionally, the absence of an outflow in off-stream reservoirs contributes to faster sediment and nutrient buildup compared to natural waterbodies.

On-stream reservoirs are commonly created by building a dam across a stream or river, resulting in a distinct straight boundary. These reservoirs exhibit an elongated, branching shape, often with a narrow profile, indicating their formation in previous valleys. Larger on-stream reservoirs are typically positioned downstream to collect water from a broader drainage basin, which can lead to increased nutrient and sediment levels compared to natural waterbodies. Due to receiving direct runoff from streams or land with limited wetland influence, on-stream reservoirs can experience significant fluctuations in water levels in response to rainfall events.

Human civilizations depend on engineered water systems to ensure a secure and reliable water supply for diverse needs, including drinking, irrigation, and industrial activities. Reservoir construction has emerged as a vital component in supporting and advancing human societies. However, the significant increase in reservoir development in the past century has initiated an ongoing exploration to comprehend the consequences of human manipulation of hydrological patterns on ecological systems and the interconnected human systems.

Water plays a critical role in supporting the growth and sustainability of agriculture and forestry lands, necessitating effective management practices. Constructing ponds for water harvesting presents an opportunity for conserving water resources. To identify suitable pond locations, watershed analysis and GIS have emerged as valuable tools. The integration of these technologies enables the assessment of site suitability for pond construction, considering factors such as terrain slope, soil composition, land utilization, and hydrological characteristics. This paper aims to explore the latest advancements in identifying potential pond sites for irrigating agriculture and forestry land through the utilization of watershed analysis and GIS.

Remote Sensing and GIS Techniques:

The advent of remote sensing and GIS techniques has brought about a transformative impact on the management of water resources. Remote sensing data offers valuable insights into crucial factors like vegetation cover, land use, soil moisture, and surface temperature, enabling the identification of suitable locations for pond construction. By employing GIS-based analysis, the integration of such data facilitates a comprehensive understanding of the spatial arrangement of water resources. This advanced approach enhances decision-making processes related to water resource management.

In recent times, numerous research endeavors have utilized remote sensing and GIS techniques to pinpoint prospective locations for constructing ponds. For instance, Wang et al. (8) employed these advanced technologies to identify suitable sites for water harvesting in China's Guanzhong Plain. By leveraging Landsat 8 satellite imagery, the researchers assessed factors such as vegetation cover, slope, and land use. Through the utilization of ArcGIS software, potential pond sites were determined based on predefined criteria.

Similarly, De Oliveira et al. (9) conducted a study in the Brazilian semiarid region, utilizing remote sensing and GIS techniques to locate suitable sites for pond construction. The researchers analyzed Landsat 8 satellite imagery to assess factors such as vegetation cover, slope, and soil type. By employing ArcGIS software, potential pond sites were identified based on a predefined set of criteria.

Multi-Criteria Decision Analysis (MCDA):

Multi-criteria decision analysis (MCDA) is a method that assesses various criteria to determine the suitability of a site for water harvesting. By considering multiple factors, this approach aids decision-makers in identifying optimal locations for pond construction based on predefined criteria.

MCDA has been widely employed in several studies for identifying potential pond sites. For instance, Elnaggar et al. (10) utilized MCDA to identify suitable sites for water harvesting in the El-Salam Canal Basin in Egypt. The researchers established a set of criteria, encompassing soil type, slope, land use, and water availability, to evaluate and pinpoint potential areas for constructing ponds.

Likewise, Jat et al. (11) employed the multi-criteria decision analysis (MCDA) approach to identify prospective locations for pond construction in the Upper Bhima River Basin in India. Their study incorporated a range of criteria, such as slope, land use, soil type, and rainfall, to assess and determine potential sites suitable for constructing ponds. By considering these factors, the researchers aimed to identify areas with favorable conditions for effective water harvesting and management.

Machine Learning (ML) Algorithms:

The utilization of machine learning algorithms has gained momentum in the identification of suitable sites for pond construction. These algorithms leverage diverse data inputs, including topography, soil type, and land use, to predict optimal locations for pond establishment.

Multiple studies have employed machine learning algorithms to pinpoint potential sites for pond construction. For instance, Yeganeh et al. (12) utilized random forest and support vector machine algorithms to identify suitable locations for water harvesting in Iran's Rangeland Watershed. The authors integrated factors such as slope, soil type, and land use into their models to identify potential pond sites accurately.

3 Methodology

3.1 Chapter objective

The purpose of this chapter is to establish a well-organized framework for conducting the study and to enhance understanding of the subject matter. Within this chapter, we will delve into the methods employed for collecting and processing data, as well as the procedures involved in water analysis and the identification of potential pond locations.

3.2 Data and method

3.2.1 Watershed Analysis

Utilizing GIS, stream network analysis is a robust method for examining the properties of stream networks and watersheds. By incorporating spatial data such as digital elevation models and hydrologic information, this approach enables the modeling and evaluation of water flow throughout a network of streams and rivers. The outcomes, which include the delineation of stream networks and watersheds, offer valuable insights for various purposes such as land utilization, water resource management, and ecological conservation. In a similar vein, a study conducted by Abdollahi et al. (13) employed GIS-based stream network analysis to evaluate the hydrological attributes of an Iranian watershed. The investigation utilized digital elevation model (DEM) data and hydrological modeling methodologies to examine the drainage pattern, flow accumulation, and properties of the stream network within the watershed.

Surface runoff plays a vital role in the hydrological system as it integrates the characteristics of the drainage pattern and hydrological properties. The analysis of runoff and stream networks is essential in hydrology as it provides valuable information about the spatial arrangement, geographic features, and hydrological attributes of a watershed. Bailey et al. (14) conducted a study that utilized stream network analysis to identify suitable locations for river basin restoration in the United States. They employed GIS techniques to evaluate the connectivity of the stream network, the morphology of the channels, and the presence of barriers that hinder fish movement. These analyses helped in determining priority areas for stream restoration. Digital Elevation Model (DEM) was a valuable data source used for terrain analysis and characterization of hydrological and topographic features.

In fact, DEM has become an essential tool for analyzing the earth's surface digitally. Significant progress has been made in the extraction of river networks based on DEM, making it an efficient approach for stream network analysis.

Stream network analysis using GIS is a valuable tool for assessing areas susceptible to flooding or erosion. By studying the water flow within the stream network and pinpointing locations of water accumulation or rapid flow, decision-makers can identify high-risk areas for potential flooding or erosion. This knowledge is crucial in making informed land use decisions, such as selecting suitable sites for infrastructure or avoiding development in vulnerable areas to mitigate the risk of flood-related damages.

Stream network analysis using GIS is also employed to identify areas that are prone to water quality degradation. By examining the water flow within the stream network and identifying locations where pollutants accumulate, decision-makers can identify areas where water quality is at risk. This knowledge aids in making informed water management decisions, such as prioritizing conservation initiatives or implementing measures to mitigate pollutant loads.

Stream network analysis using GIS is a valuable tool that enables a comprehensive understanding of the intricate interactions among water, land, and human activities within a specific geographical region. It empowers decision-makers to pinpoint areas with heightened vulnerability to flooding or erosion, as well as locations where water quality may be compromised. By leveraging this information, informed choices can be made regarding land and water management, fostering sustainable development and safeguarding fragile ecosystems. In figure 5 you can the basic flow of any stream network analysis.

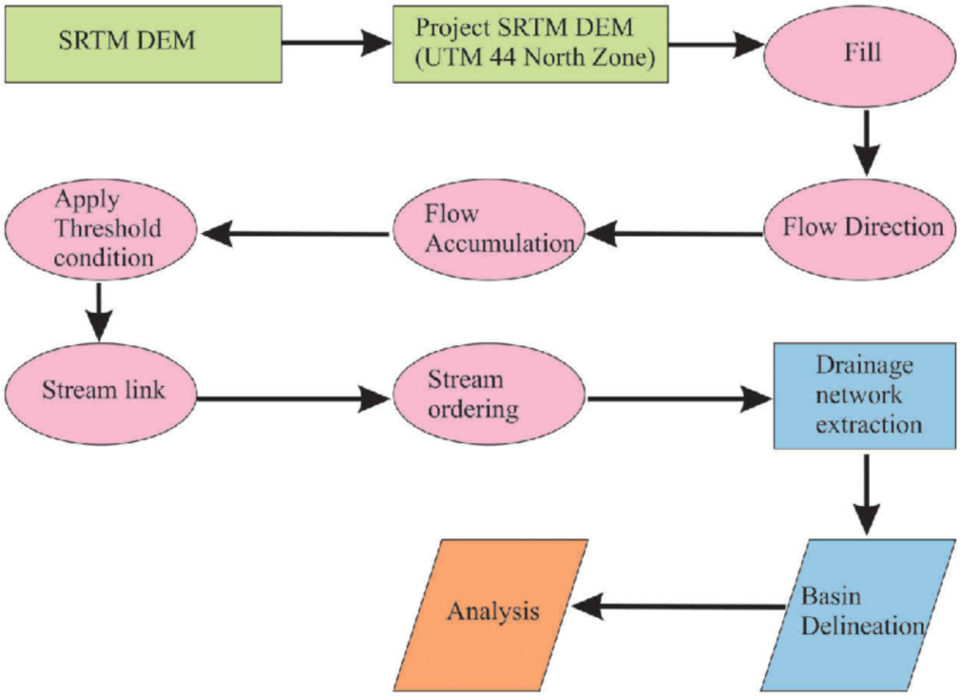


Figure 5. Basic Flow chart of stream network analysis

3.2.2. Well and pond location identification

The utilization of GIS in the identification of favorable sites for wells and ponds entails examining spatial information to identify areas that possess suitable hydrological and geological attributes. This approach typically involves integrating digital elevation models, soil data, and other spatial data to precisely identify locations that are optimal for the placement of wells and ponds (15).

The utilization of GIS for locating wells and ponds serves multiple objectives, such as managing water resources, facilitating irrigation, and planning water supply systems. By identifying appropriate areas for these water sources, stakeholders can strategically position them, mitigating the potential for environmental contamination or other adverse impacts.

A commonly employed method for identifying suitable locations for wells and ponds using GIS involves integrating various spatial data layers to identify areas that possess desirable hydrological and geological features. For instance, the utilization of digital elevation models enables the identification of regions with appropriate surface water flow patterns, while the analysis of soil data facilitates the identification of sites with favorable water retention properties (16).

After identifying areas with favorable characteristics, additional analysis can be conducted to assess the suitability of specific locations for well and pond placement. This assessment may involve evaluating water quality and the potential risk of contamination from nearby sources.

In summary, the utilization of GIS in the identification of appropriate sites for wells and ponds is an invaluable tool for determining optimal placements of these essential water resources. It assists in making informed decisions regarding water resource management, irrigation, and water supply planning, all while mitigating adverse environmental consequences.

3.2.3 Pond Calculation

The calculation of pond capacity is crucial in determining the maximum amount of water that a pond can hold. This calculation is necessary when designing and building ponds for different applications, such as water storage, aquaculture, and managing stormwater. Various methods, including analytical, empirical, and numerical approaches, can be used to calculate pond capacity. These methods consider factors such as the shape, size, and depth of the pond, as well as the characteristics of the soil and vegetation within the pond basin. (17).

The estimation of pond capacity using monthly maximum precipitation involves determining the maximum volume of rainfall that a pond can capture and retain over a specific time frame. This method is valuable when designing and constructing ponds for managing stormwater or controlling floods (18).

To calculate pond capacity using monthly maximum precipitation, the following steps can be taken:

1. Obtain the maximum anticipated precipitation amount for a specific duration, such as a month or a year, by referring to historical precipitation records or climate projections.
2. Estimate the runoff coefficient for the vicinity of the pond, which indicates the proportion of rainfall likely to result in surface runoff and contribute to the pond's inflow. This estimation relies on factors such as land use and soil properties within the area.
3. Estimate the contributing area of the pond, which encompasses the total land area that directs water flow into the pond. This estimation can be derived by analyzing topographic maps or utilizing GIS software.

4. Multiply the maximum rainfall with the contributing area and the runoff coefficient to calculate the overall volume of water anticipated to flow into the pond within the specified timeframe.
5. Subtract any losses caused by infiltration or evaporation from the total volume of water to determine the effective capacity of the pond, representing the amount of water it can retain.
6. Compare the effective capacity of the pond, considering the net volume of water, with the actual capacity of the pond to assess its suitability for the desired application.

It should be emphasized that this methodology provides an approximation of pond capacity based on anticipated precipitation and runoff. The actual capacity of the pond may be lower due to factors like sediment deposition or vegetation encroachment within the pond basin. Hence, regular maintenance and monitoring of the pond are crucial to ensure its optimal performance and effectiveness (19).

3.3 Data collection and processing

3.3.1. Watershed data collection and processing

As we mentioned before a Digital Elevation Model (DEM) represents the topographic surface of the Earth, excluding any surface objects such as trees and buildings. It provides a bare earth model by displaying the Earth's surface elevation in a digital format. DEMs can be generated from a range of data sources. The DEM data of the study area were collected from the webiste of the EarthExplorer (EE) user interface, developed by the United States Geological Survey (USGS), provides online search, browse display, metadata export, and data download of satellite, aircraft, and other remote sensing inventories. As shown in the figure 6, for the watershed analysis, in this study, these 6 six DEM files which included the study area were downloaded as GeoTiff (.tiff) files.

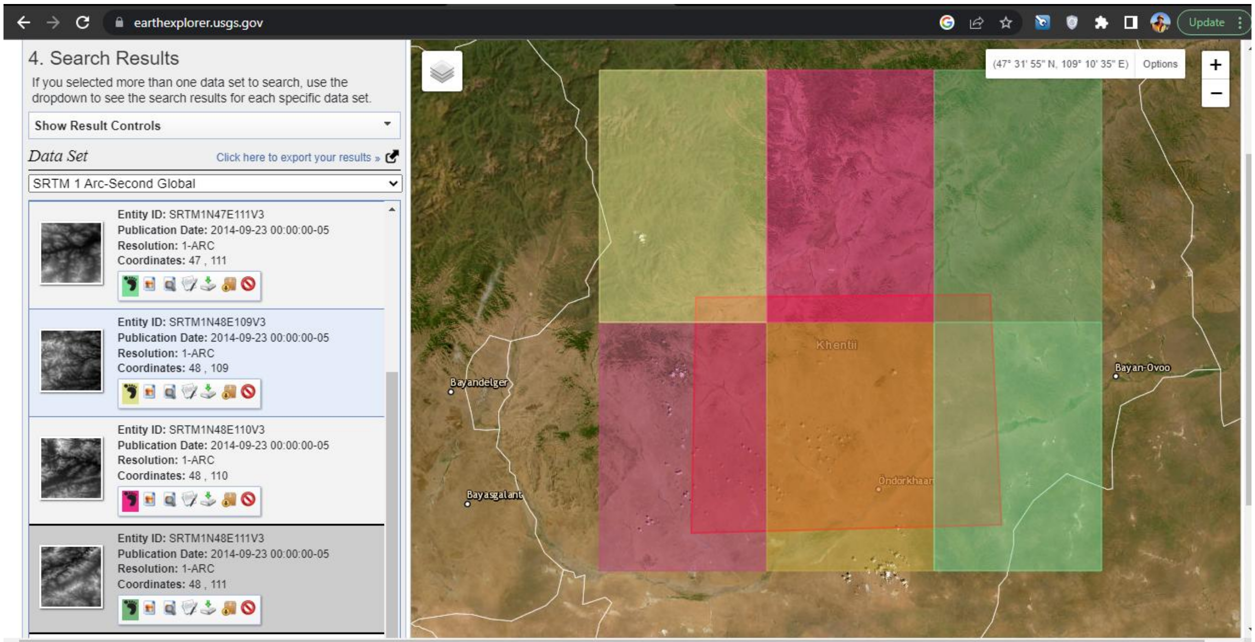


Figure 6. Interface of the USGS earth explorer Website

After the successful download of the DEM data, downloaded files were moved into a specifically designated folder to be used in the program ArcGIS. In this study, for our data analysis and mapping, ArcMap 10.8 software was utilized to obtain the desired results. It should be noted that the geographic coordinate system was set to WGS 1984 earlier and the projected coordinate system was set to UTM, WGS 1984, Northern Hemisphere, and WGS 1984 UTM Zone 48N. In order to obtain the intended outcomes for our watershed analysis, we underwent ten data processing steps. As a step-by-step process, these analysis processes were included in this chapter.

The first step in our analysis was to use fill tool on our DEM Files. As shown in figure 7, fill is a geoprocessing tool that fills sinks in a surface raster to remove small imperfections in the data. Sinks, as well as peaks, are commonly encountered errors caused by data resolution or elevation rounding. To ensure accurate delineation of basins and streams, it is necessary to fill these sinks. Failure to do so may result in a fragmented drainage network. The filling process involves iterating until all sinks within a specified elevation limit are addressed. As sinks are filled, new ones may emerge at the boundaries of the filled areas, which are then addressed in subsequent iterations.

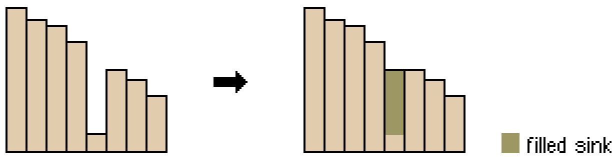
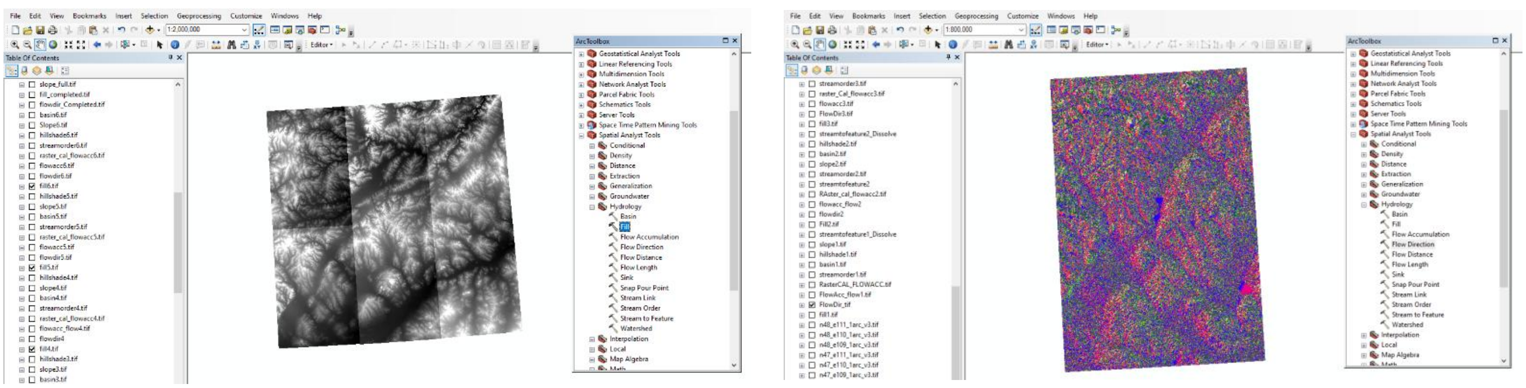


Figure 7. Profile view of a sink before and after running Fill

Figure 8. Filling and Getting Flow Direction



A. B.

As shown figure 8.B, our next step is getting the flow direction of previously filled raster data. A crucial aspect of analyzing hydrological characteristics is determining the flow direction from each cell in a raster. This is achieved using the Flow Direction tool, which takes a surface as input and generates a raster indicating the direction of flow from each cell. The specific coding representing the flow direction can be found in Figure 9. For clarity, these geoprocessing analyses were performed on all six DEM files one by one, because even though we fixed the sinks and peaks, our data still had errors, which were blue and red areas, as you can see in Figure 8.B.

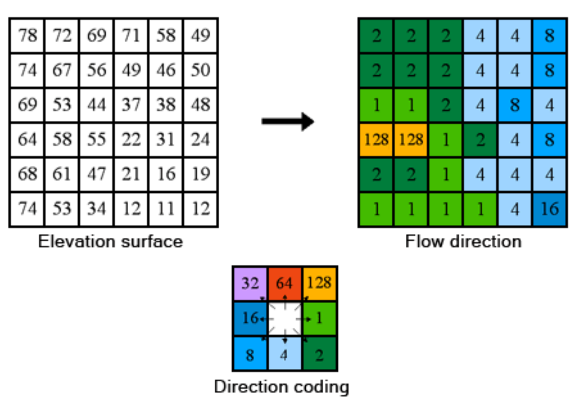


Figure 9. The coding of the direction of flow

The Flow Accumulation tool calculates accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster. In figure 11.A, it shows how determined flow direction data converted into accumulated flowlinesWhen a weight raster is not provided, a default weight of 1 is assigned to each cell. The resulting output raster represents the count of cells that flow into each cell. Figure 10 displays the direction of travel from each cell in the top left image, while the top right image shows the number of cells that contribute flow to each cell.

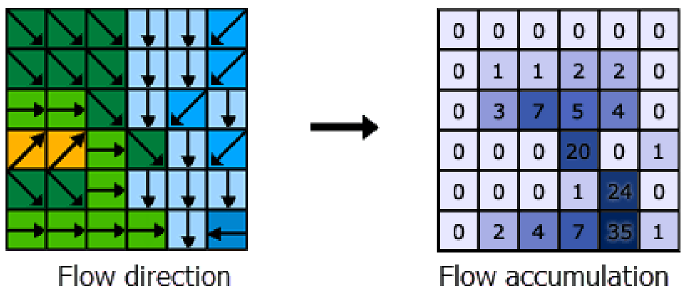


Figure 10. Determination of the accumulation flow

In figure 11.B, in the next step the Raster Calculator is used which is a tool that enables users to conduct mathematical operations on raster datasets or multiple raster layers. Through the use of mathematical expressions or conditional statements, existing raster layers can be manipulated and combined to generate new raster layers. The Raster Calculator serves as a valuable tool for processing and analyzing geospatial data, enabling the extraction of valuable insights from the data. The input data was previous flow accumulation data and the conditional mathematical expression was “"FlowAcc_flow1.tif">1076”, in this case 1076 is lowest elevation point of our data.

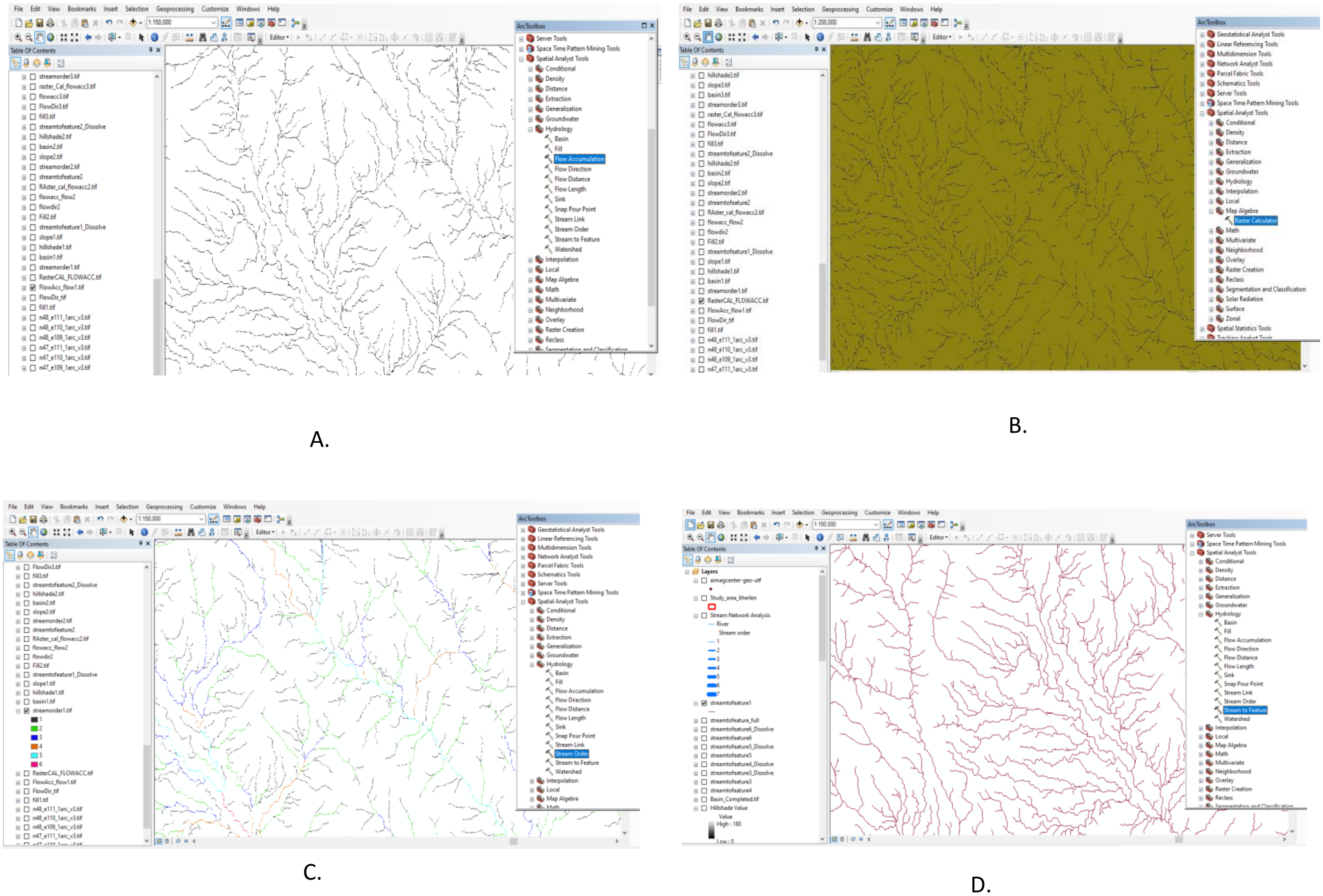


Figure 11. Stream Analysis Procedures

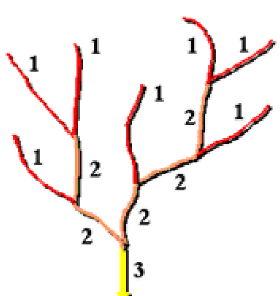


Figure 12. Strahler stream ordering

The fifth step in stream network analysis involves determining the stream order, which is a process of assigning numeric values to links in a stream network. This classification method enables the identification and categorization of different stream types based on their tributary numbers. Understanding the stream order provides insights into various stream characteristics. For example, first-order streams primarily rely on surface water flow and lack concentrated upstream flow. Consequently, they are more susceptible to non-point source pollution and greatly benefit from wide riparian buffers compared to other parts of the watershed. Stream order increases when two links of the same order intersect. Therefore, the intersection of two first-order links creates a second-order link, while the intersection of two second-order links results in a third-order link, and so forth. As shown in figure 11.C, there were defined 6 stream orders. In this step, we used a method called the Strahler stream ordering method.

As shown in figure 11.D, our next step is using stream to feature tool. The Stream to Feature tool employs an algorithm primarily intended for converting stream networks or similar linear raster networks into vector format, assuming directionality information is available. The tool is optimized to utilize a direction raster, facilitating the conversion of intersecting and neighboring cells into vector features. Our input data is flow direction and previous raster calculated data.

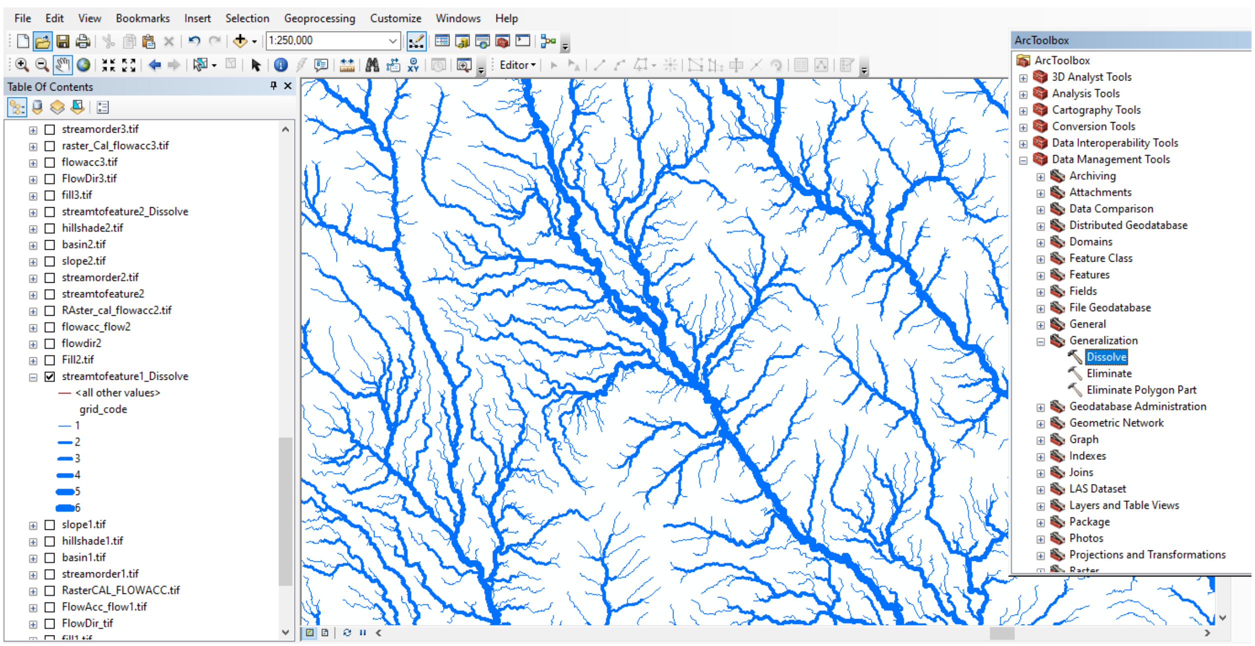


Figure 13. Visualization of Stream order

The last step of our stream network analysis is visualization of stream order. To do this we dissolved our data by its grid code which only contains stream orders. As we can see from Figure 13, as the width of the stream gets bigger its stream order increases. The dissolve tool is a function for processing spatial data that allows for the merging of neighboring polygons into a single polygon based on a shared attribute. This function dissolves the common boundaries between the adjacent polygons, creating a single new polygon with a single set of attributes which can be seen from figure 14.

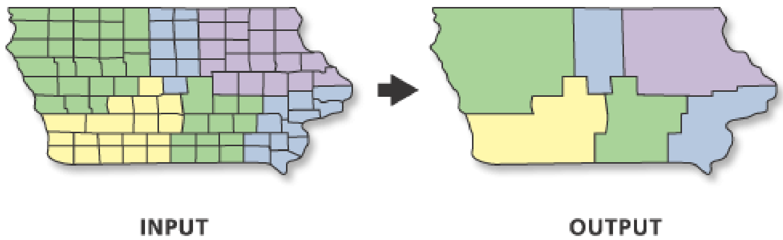


Figure 14. Illustration of Dissolve tool

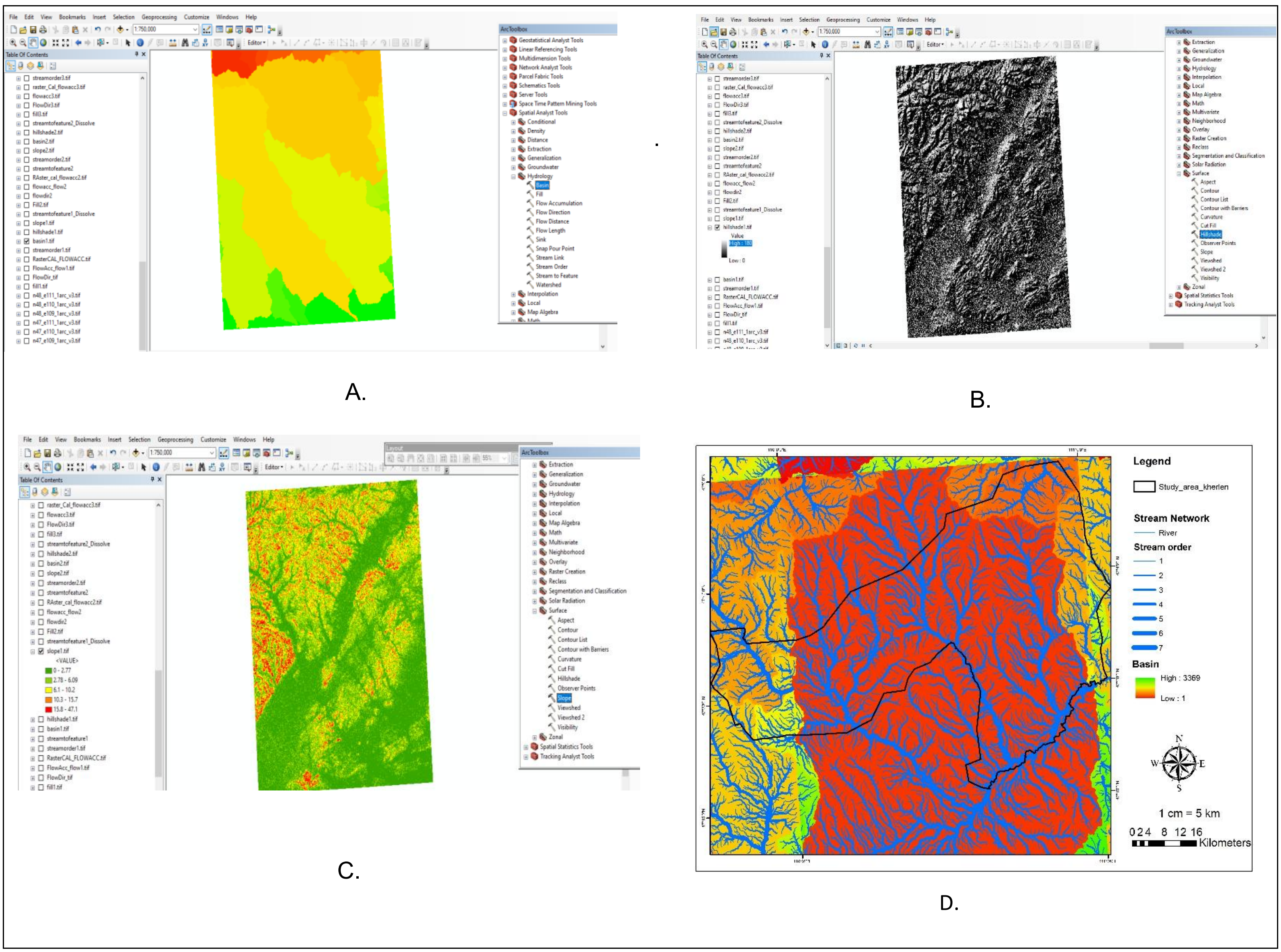


Figure 15. Additional Analysis on ArcGIS

Our next procedure is Basin Delineation which is done by Basin tool is illustrated in figure 15.A. To delineate drainage basins within the designated analysis area, the process involves identifying ridge lines that separate the basins. By examining the input flow direction raster, connected cells belonging to the same drainage basin are identified. The creation of drainage basins involves locating pour points at the analysis window's edges (where water would exit the raster) and sinks, and determining the contributing area above each pour point. This ultimately generates a raster representing the drainage basins.

In figure 15.B, we can see that our next additional procedure is illumination of surface by hillshade tool. The Hillshade function generates a 3D grayscale depiction of the terrain surface, considering the sun's position to create shading effects in the image. Hillshading is a visualization technique that represents terrain based on the interaction between a light source and the slope and aspect of the elevation surface. It provides a qualitative representation of topography and does not provide precise elevation values.

The slope is a measure of the steepness or inclination of the terrain, indicating how much the elevation changes in relation to the horizontal distance for each cell in a digital elevation model (DEM). Calculating the slope accurately provides valuable insights into the land's suitability for various purposes like agriculture, forestry, or urban development. It serves as an important criterion in the identification of suitable locations for ponds.

After all data processing was done we extracted the data associated with our study area and separated it from the rest. From Figure 15.D, we can see that the Kherlen soum area mostly lies in the Kherlen River basin which is the area covered in red color. One of the most important maps is Stream Network Analysis of Study Area with Elevation data which is shown in Figure 16. Using this map we will determine potential pond location and variations of agriculture and forestation area in the next chapter. Also from Figure 17, we can see our watershed analysis flow chart with all 10 processes, and how it is related to each other.

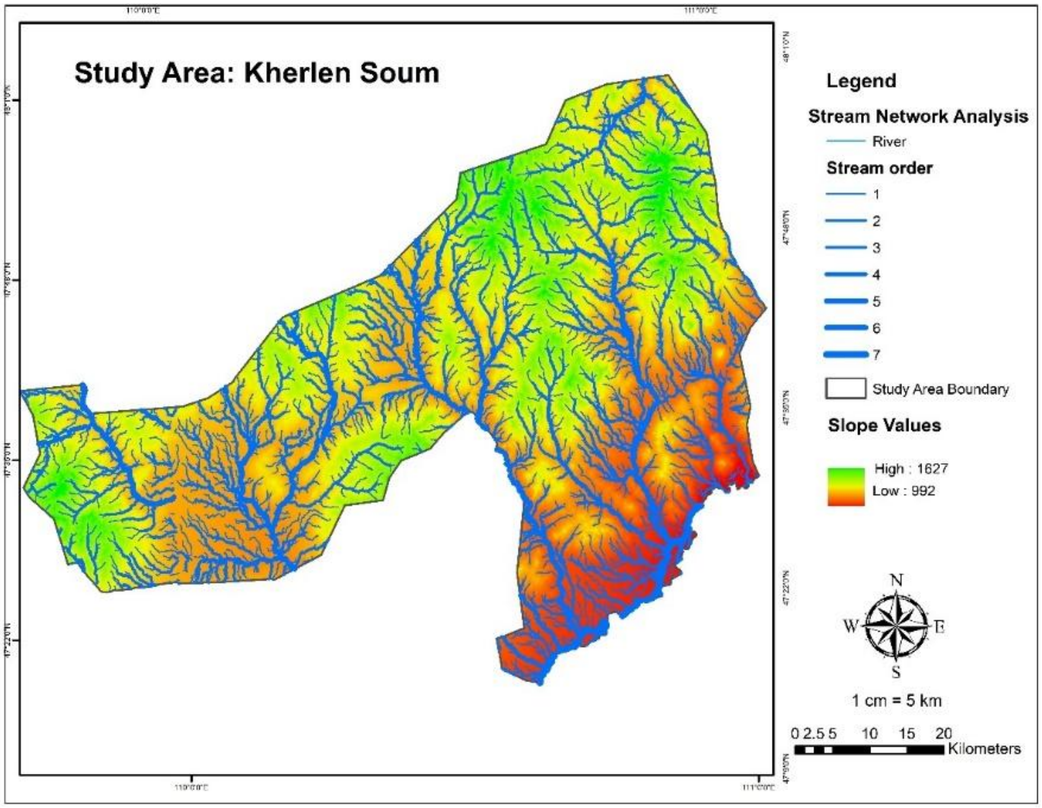


Figure 16. Stream Network Analysis of Study Area with Elevation Data

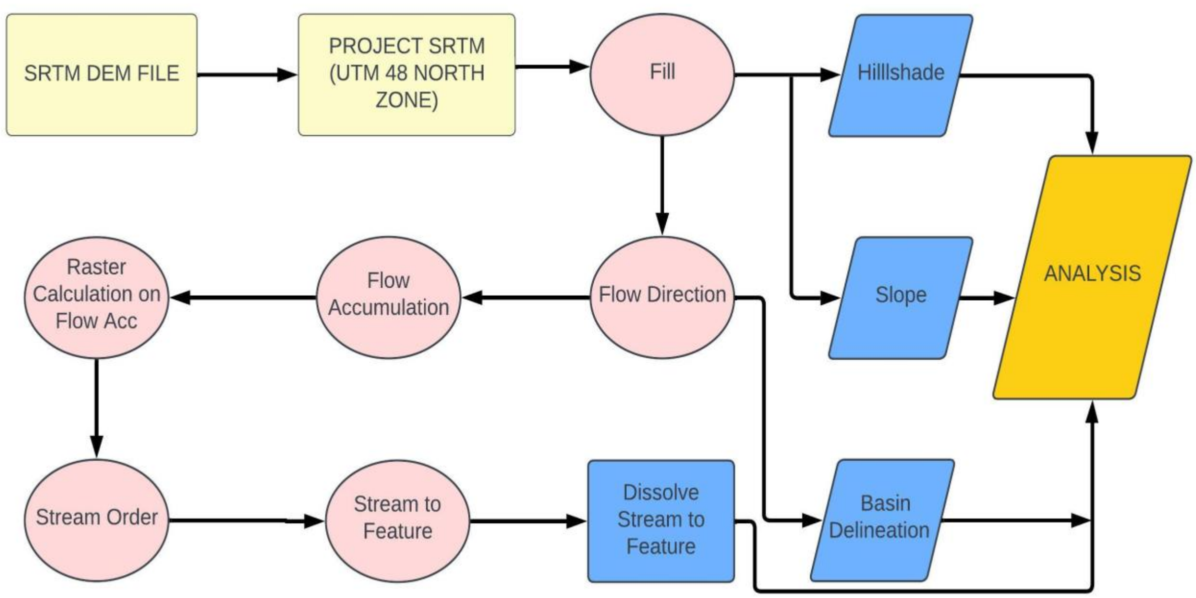


Figure 17. Flow Chart of Watershed Analysis

3.3.2. Pond data collection and processing

Cadastral map of the Kherlen soum which was taken from the government's office of Khentii province is shown in figure 17. To explain this map, parts highlighted in white are currently used for agricultural use, parts with dark green were used for agricultural use but are not used anymore, and parts highlighted in blue are private land and urban areas.

Figure 18. Cadastral map of Kherlen Soum from Land Office

To clarify, this map first was given as an AutoCAD DWG file and it needed to converted to a shapefile to be used in the ArcGIS program. When the DWG file converted to ArcGIS file it did not have any spatial reference information so we had to georeference the file. This was done by Spatial adjustment tool which is shown in figure 18. This map will be used as one of the important factor to determine the potential pond locations. For example, if our chosen pond location is near habitation, private land, or agriculture, which means if we built a pond at that exact location it will be maintained, even someone who built it could benefit by renting, etc.

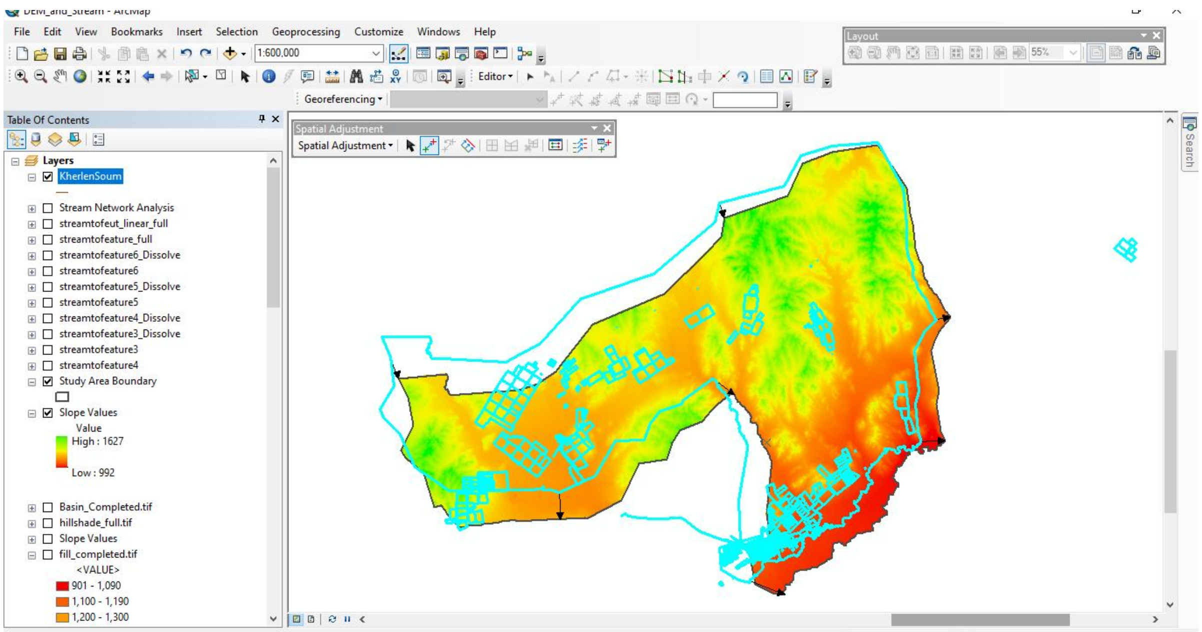


Figure 19. Georeferencing the converted shapefile

Since all the necessary data is collected and maps are created it is easy to determine the potential locations of ponds. To determine the potential pond locations we set 3 criteria. The most important criterion is it should be positioned on stream orders 4,5 and 6 which was analyzed from the stream network analysis. Because these stream orders will likely carry the most surface runoff and we can see that it is located in the most suitable flat areas which can be seen in Figure 20. The second criterion is where the pond location is there should be a reasonable flat plain area because if we build a pond there should be land such as farming can be done. The last criterion it could be better if there are active areas or urban or private areas.

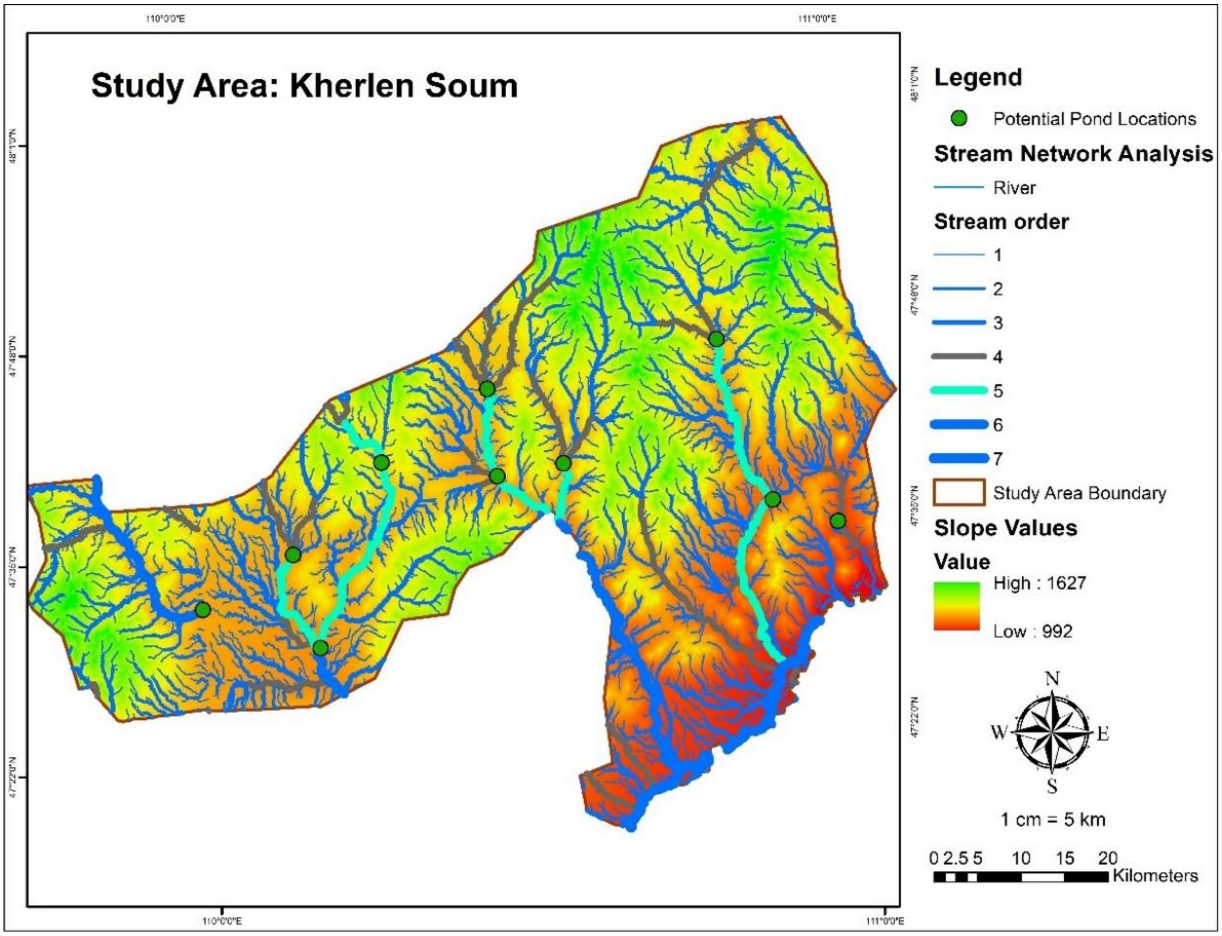


Figure 20. Potential Pond Locations

3.3.3 Pond size Calculation

The Rational Method is a popular empirical approach employed in hydrological engineering to estimate the maximum runoff rates from a given area during rainfall. It finds widespread application in stormwater management and the design of drainage systems. The method calculates the peak runoff using the following formula:

$$Q = C*I*A$$

Where: **Q** is the peak runoff rate (in cubic units per second or any consistent unit of flow)

C is the runoff coefficient, which represents the fraction of rainfall that becomes runoff

I is the rainfall intensity (in units of length per time, such as inches per hour or millimeters per hour)

A is the drainage area (in square units, such as acres or square meters)

Figure 21. Rational Method Equation

The runoff coefficient (C) considers multiple factors influencing runoff, including land use, soil type, slope, vegetation cover, and antecedent moisture conditions. It is determined empirically and can differ based on the specific attributes of the area being studied. As shown in Figure 21, for the variable 'I' rainfall intensity we will take the maximum average monthly precipitation of Kherlen station which is about 63.22 mm. In the result and discussions we will continue our calculation.

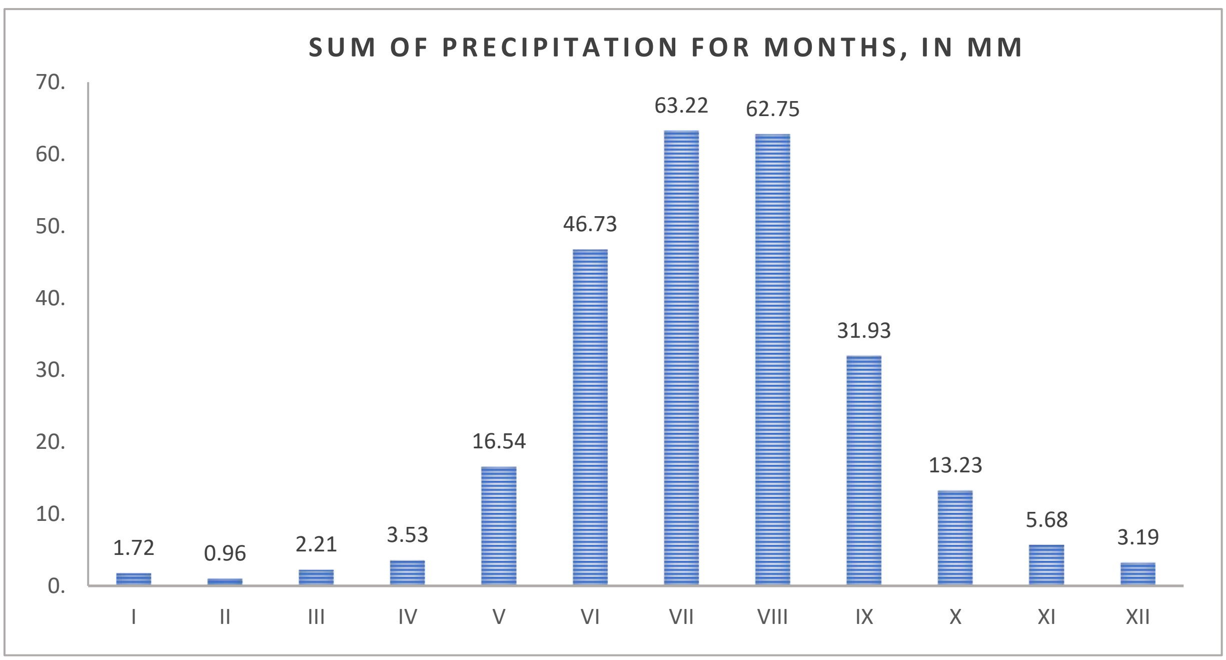


Figure 22. Average Monthly Precipitation Data of Kherlen Station from 2013-2022

4 Results and Discussion

In this study, comprehensive watershed, stream network, soil structure and land use analysis were done across Kherlen Soum area. In this chapter using this analysis and created maps we determined potential areas for forestation and we recommended it.

	Life form	
Zone or Belt	Tree	Shrubs and shrubs
Mountain forest-steppe zone	**Larix sibirica, Pinus sylvestris, Pinus sibirica, Picea obovata**	Lonicera altaica, Spirea flexuosa, Spirea media, Betula fruticosa, Juniperus pseudosabina, Rhododendron dahuricum, Rosa acicularis, Caragana pygmaea, Cotoneaster melanocarpa, Ribes diacantha, Crataegus sanguinea, Malus baccata, Sambucus manjurica, Dasiphora fruticosa
Steppe zone	**Ulmus pumila, Pinus sylvestris**	Caragana microphylla, Caragana stenophylla, Caragana bungei, Caragana leucophloea, Caragana spinosa, Caragana pygmaea, Eurotia ceratoides, Kochia prostrata
Barren steppe, desert region	Ulmus pumila, Haloxylon ammodendron, Tamarix ramosissima, Tamarix Karelinii	Kochia prostrata, Eurotia ceratoides, Artemisia xerophytica, Artemisia gobica, A.caespitosa, Salsola passerina, Caragana korshinskii, Nitraria sibirica, Lycium ruthenicum, Ephedra equisetina, Ephedra przewalskii, Brachanthemum gobicum, Ammopiptantus mongolicus, Ajania trifida, Reaumurea soongorica, Calligonum mongolicum
Mountain meadows and river meadows	Abies sibirica, Larix sibirica, Pinus sylvestris, Pinus sibirica, Picea obovata	All species of Salix, Padus asiatica, Dasiphora fruticosa, Spirea salicifolia, Ribes nigrum
Lowlands	Populus diversifolia, Elaeagnus moorcroftii, Ulmus pumila	Amygdalus pedunculata, Amygdalus mongolica, Armeniaca sibirica, Athraphaxis pungens, Kalidium gracile, Kalidium foliatum, Salsola passerina, Salsola laricifolia, Zygophyllum xanthoxylon, Anabasis brevifolia, Sympegma Regelii, Iljinia Regelii, Nitraria sphaerocarpa

Table 1. List of plant species to plant in disturbed areas.

First of all, we need to decide what kind of species of plant or tree could be planted in our study area. To choose the species we looked at Mongolian National Standard for Environment and Re-vegetation of destroyed land (20). From table 1, we can see the general technical requirements for different plants for different climate zones in Mongolia. Our study area mostly lies in steppe zone and a little bit in mountain forest-steppe zone.

Zone	The name of the plant	Spacing between rows(m)	Between the lines distance (m)	Standard for planting in 1 hectare
Mountain forest-steppe belt	**Birch, poplar, hemlock, larch, pine, spruce**	**5**	**4**	**500**
	Elm	**4**	**3**	**833**
Steppe, barren steppe, desert region	**Poplar, uliangar**	**4**	**3**	**833**
	Elm	3	3	1111
In any zone or belt	all kinds of willows and apricots, gum trees, hawthorns and gorse	2	1.5-2	2500-3333
	Currants and raspberries	3	1	3333
	Sea buckthorn	4	1.5	1666

Table 2. Standards for planting trees, shrubs, and shrubs by seedlings

According to Table 2, we suggested planting pine, poplar, and elm in these 3 trees the same amount in our suggested area. Also, we calculated the average standards for planting in one hectare as 722 which is shown in Figure 21.

(500+833+833)/3=722 (standard in 1 hectare)

Pine Elm Poplar

Figure 23. Calculation of standard for planting in 1 hectare

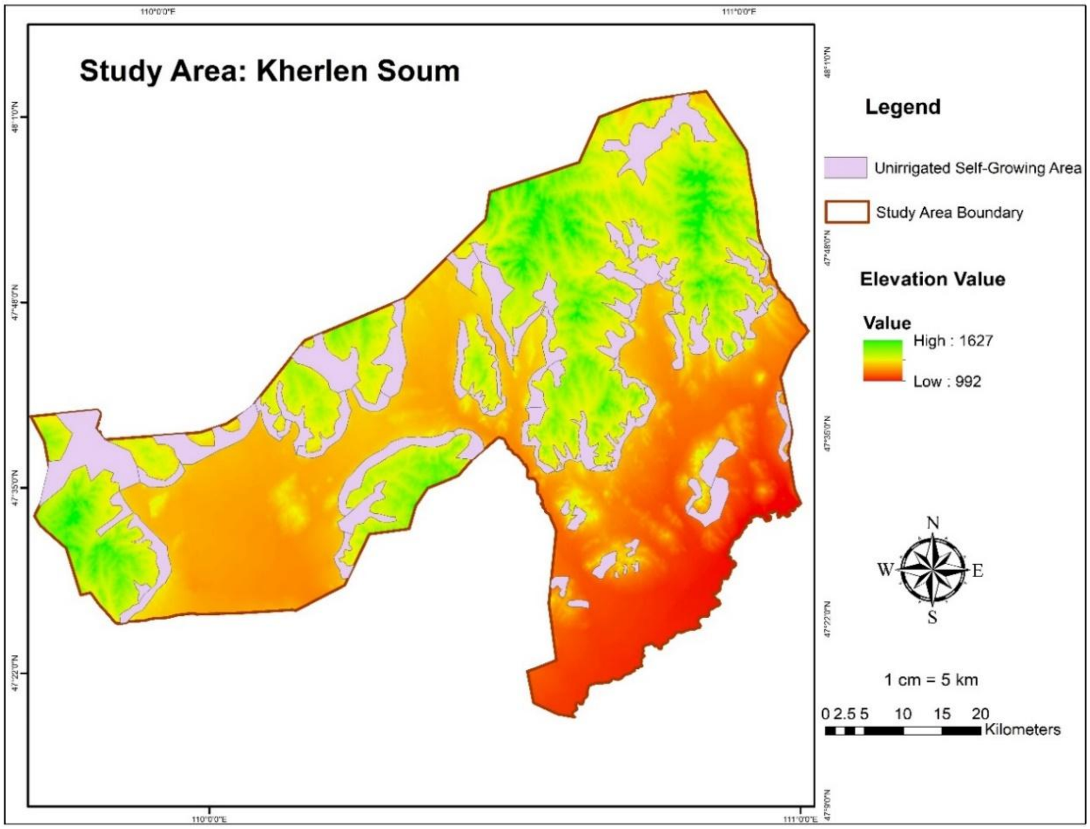


Figure 24. Recommended Area for Unirrigated Self-Growing Tree Area

Figure 25. Trees Growing in Mountain Ravine

The first area we recommend is trees will grow by themselves without any irrigation in mountain ravines. Because trees growing in mountain ravines or steep sides are usually irrigated by mountain surface runoff water meaning they will be watered by natural irrigation system. The total area covering this recommended area was about 65250.55 hectares. Kherlen Soum's area is about 380051 hectares and meaning this recommended area covers 17.16 percent of the entire study area. According to our calculation of the standard for planting in one hectare, this is a natural reserve area for 47,110,500 units of trees and bushes.

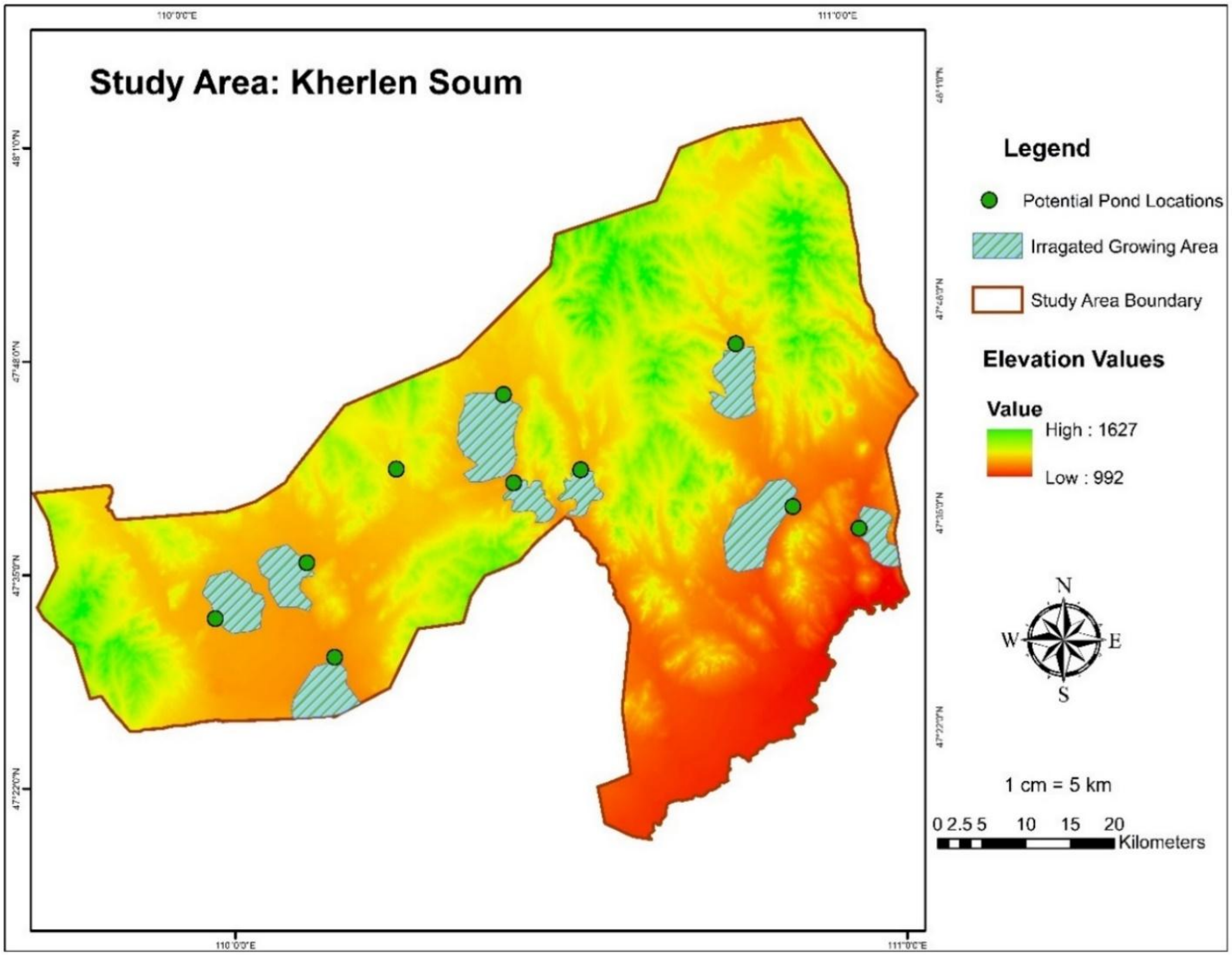


Figure 26. Recommended Area for Irrigated Growing Tree Area

The second area we recommended is the area that is irrigated by our identified potential pond locations. To irrigate the plants in this area will use a channel or canal irrigation system. This is because the areas we have defined are mostly geographically downstream from the ponds to the afforestation areas. But if in some areas it is not possible to irrigate by this method, maybe we would need to use pump water in that area or we could build a well near that location. To clarify, these recommended areas did not overlay with urban areas, farmland, and private land, which makes new fertile lands for any kind of agriculture or afforestation and this is the reason why that one pond location has no area near it. If we compare it our study area, this area covers 7.38 percent of Kherlen soum. The total area covering this suggested area is about 28050.59

hectares, which is a new natural afforestation area for 20,252,100 units of trees and bushes.

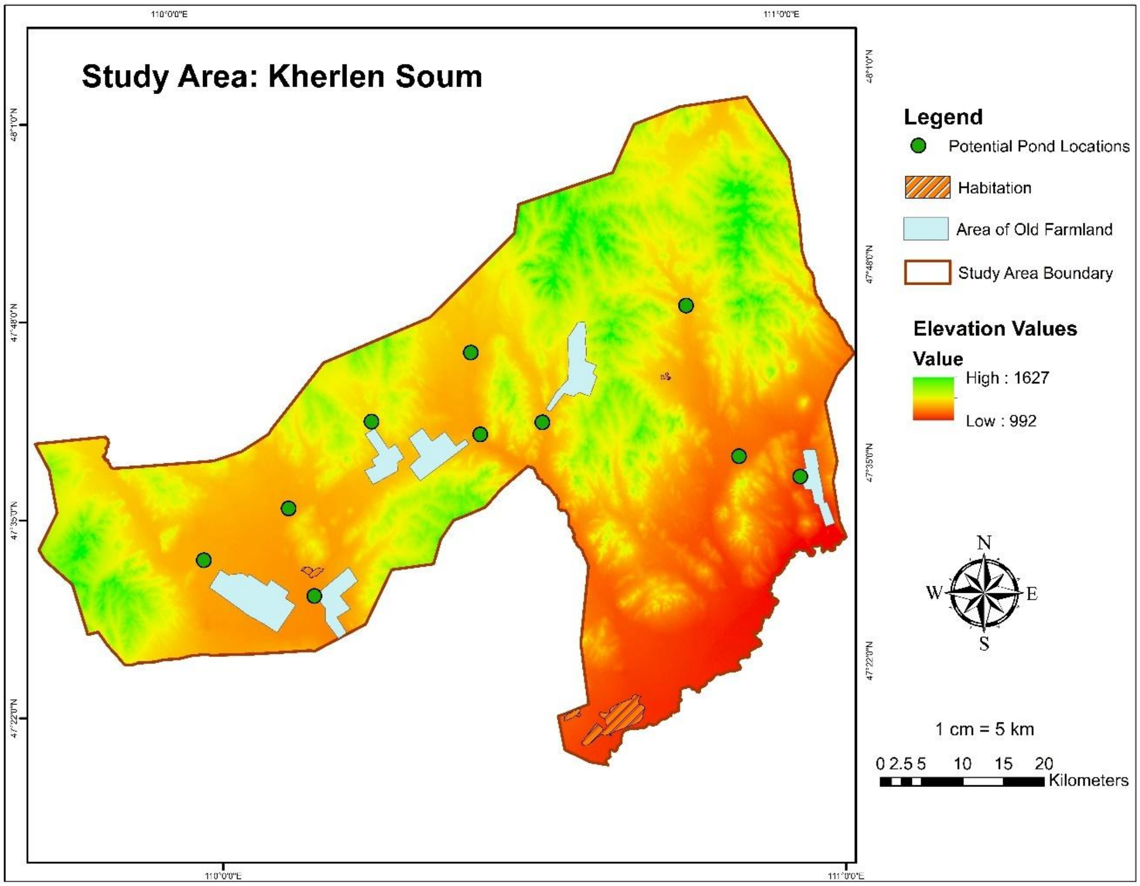


Figure 27. Recommended Area for Forestation of Old Farmlands

The third area we recommended is the area which had been used before as a field of crops, which now is not used anymore for any purposes. These areas are defined based on the cadastral map of Kherlen Soum. As we mentioned before as a result of the victory of the democratic revolution in 1990, Mongolia transitioned from socialism to democracy and a free market society (21). In addition, Khentii Province was the main agricultural field in the eastern region of Mongolia. These defined areas need to be fertilized before using as afforestation areas. For the irrigation of the areas, we could use the previously determined ponds and we could solve the irrigation problem by building a well. The total area of the recommended area is about 13700.4 hectares which is a reserve afforestation area of 9,891,400 units of trees and bushes. Comparing it to our study area, it covers 3.6 percent of Kherlen soum.

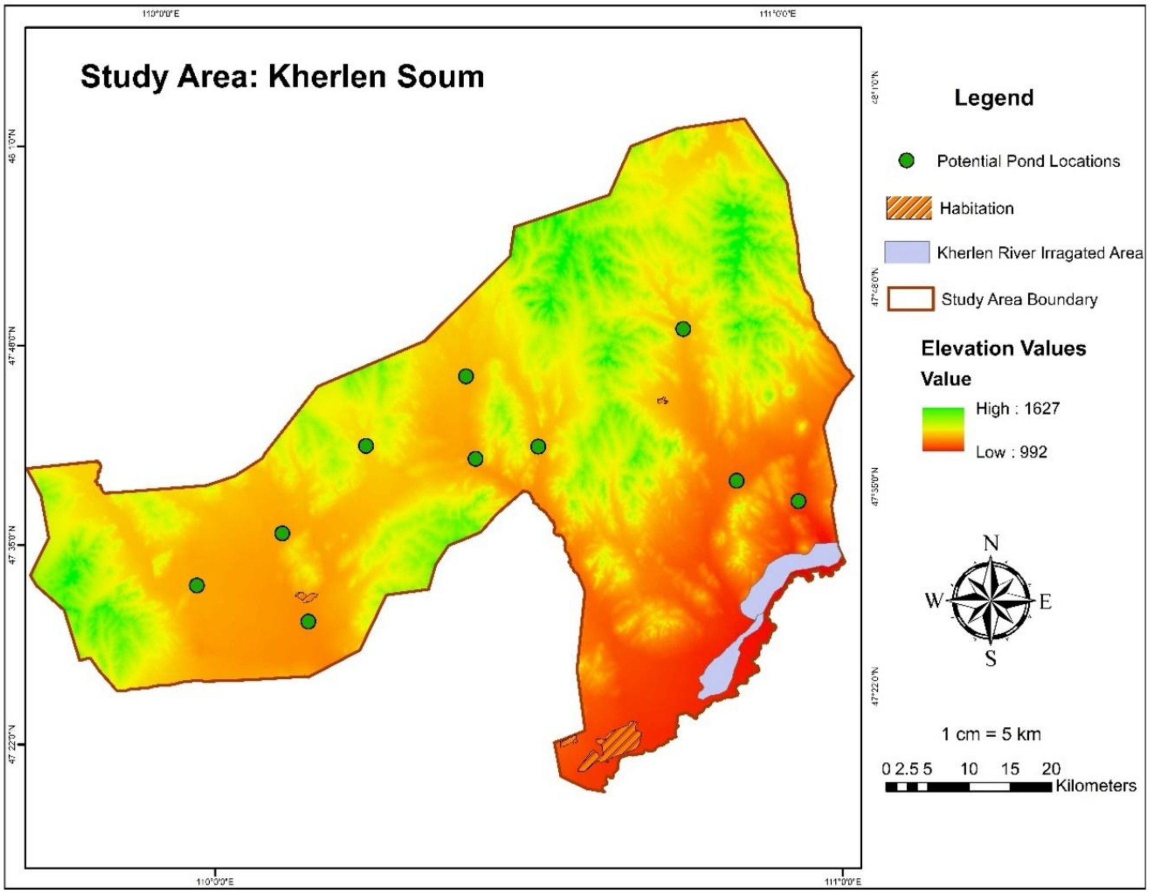


Figure 28. Kherlen River Irrigated Area

The last recommended area is the Kherlen River irrigated area. Since our study fully lies in the Kherlen River basin it will be a big mistake if we do not use the biggest reliable water source. However, we could not suggest larger new afforestation areas, because more than 50 percent of the southeastern part of Kherlen Soum is used for agriculture. Because most of the area is plain which makes it very suitable for agriculture area with the Kherlen River flowing just there. In addition, if we define areas far from the bank of the Kherlen River it will be costly to transport water to our defined area. The total area of our Kherlen River Irrigate area is about 5,783.4 hectares which about 1.52 percent of our study area. It will be new reserve forestation area for 4,175,615 units of trees and bushes.

This paragraph will give us technical advice on tree planting in our recommended area, and strictly follow the following recommendations for better results. Trees and shrubs can be planted in spring from mid-April to mid-May in desert and steppe regions, and from early May to early June in woodlands and steppes. Plant in the recommended area at least 20 days before the ground freezes in any region in autumn, or between September 25 and November 1. The height of tree saplings to be planted in rehabilitation should be at least 1.5 m, with 2-3 or more branched branches, fruit seedlings should not be lower than 50 cm, with 2-3 branched branches.

All types of planting materials (such as seeds and seedlings) for regeneration are healthy and normal development, not affected by diseases or pests, not damaged by freezing. It is recommended to monitor the forestation land during the preparation of fertilizers and plant seeds in August of the 2nd year, and the results of reforestation shall be handed over to the relevant government authorities in the 3rd year. It is accepted to hand over to governments when the life of trees, mushrooms and shrubs is more than 70%, and grasses are more than 90%.

In the last part of the results and discussion we determined pond size using surface runoff. To calculate the runoff rate we have to determine runoff coefficient ‘C’. First of all we have to define our soil group of study area using figure 24, then we can find runoff coefficient by using table 1. Kherlen soum’s steppe area’s soil type is considered as A group soul and mountainous area’s soil classified as C group soil. In figure 29, hydrological A, B, C, D 4 soil group is shown.

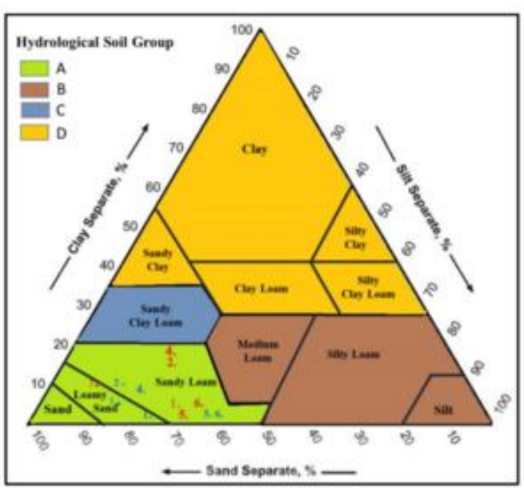


Figure 29. Soil Classification

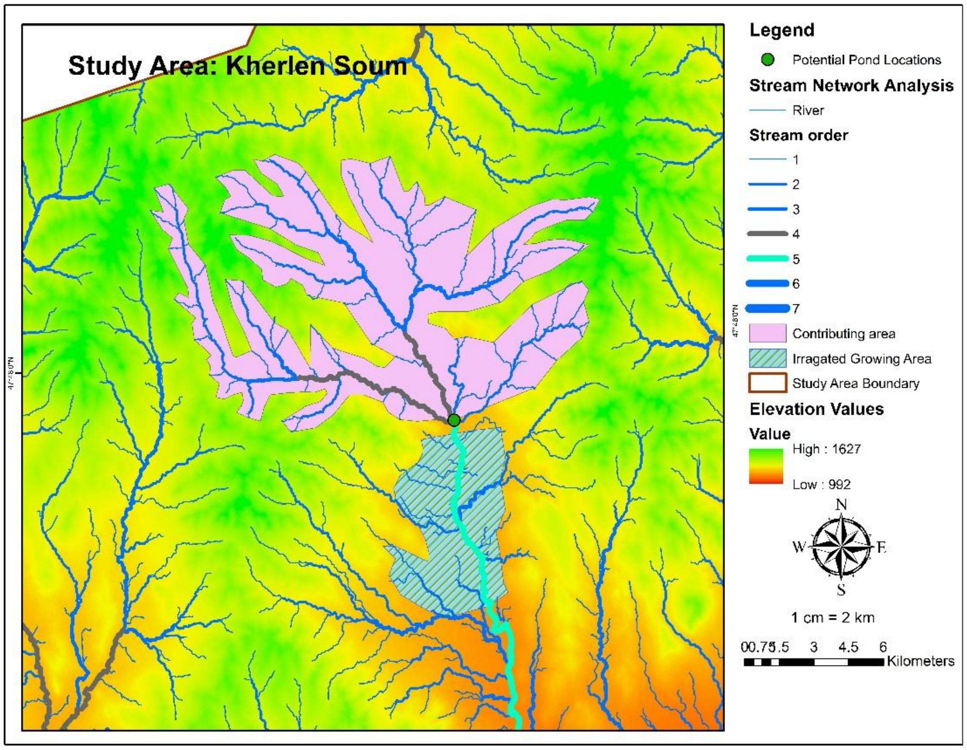


Figure 31. Contributing Area to the Pond

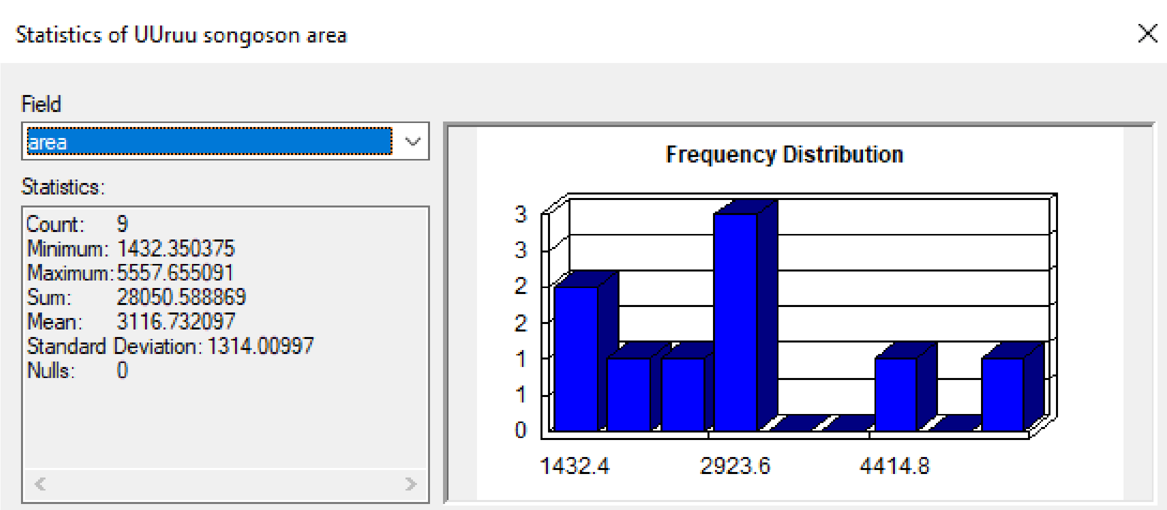


Figure 30. Statistics of Irrigated Growing Tree Areas

To calculate the example pond size we used Figure 31 which shows us the contributing area as pink and the example pond area as grey. As you can see these ponds' average area was about 3116 hectares so we choose the pond location which had a close area it which is about 3140 hectares. Using the Figure 21 equation we calculated that the peak runoff rate is about Q=C*A*I=0.2*104,978.345m2*0.063m = 1,327,346 m3 per month. For clarification, C was taken as 0.2 from Table 3, because our chosen area is a mountainous area which means its soil group is C and the Land Use Land Cover (LULC) is a forest with a slope higher than 6 percent.

We calculated the water demand of the corresponding irrigated growing area. As we asked from a professional agronomist seedlings of any tree need to be watered 2 times a week and its planting hole can be refilled 2-3 times per one time of watering. We considered the planting hole volumes as 20L. So we calculated the water demand of that area as V=3140*722*20*3*2*4=1,088,198,400L=1,088,198,4 m3 water per month. Where 3140 is the area, 722 is trees or busher per hectare, 20 is planting hole volume, 3 is refilling times, 2 is water per week, and 4 is watering per month. From this calculation, we can see that this area is suitable for irrigated growing area.

For the pond size of 1,327,346 m3 we have many options of dimensions. For example: Length is about 450m, width is 200m, and depth is 15m. To determine the suitable dimensions of pond we have to study the area and suggest suitable dimensions to that area.

LULC	**Runoff Coefficient**											
	Soil Group A			**Soil Group B**			**Soil Group C**			**Soil Group D**		
Slope	<2%	2%–6%	>6%	<2%	2%–6%	>6%	<2%	2%–6%	>6%	<2%	2%–6%	>6%
Cropland	0.14	0.18	0.22	0.16	0.21	0.28	0.20	0.25	0.34	0.24	0.29	0.41
Forest	0.08	0.11	0.14	0.10	0.14	0.18	0.12	0.16	0.20	0.15	0.20	0.25
Grassland	0.15	0.25	0.37	0.23	0.34	0.45	0.30	0.42	0.52	0.37	0.50	0.62
Mixed vegetation	0.14	0.22	0.30	0.20	0.28	0.37	0.26	0.35	0.44	0.30	0.40	0.50
Artificial Surfaces	0.33	0.37	0.40	0.35	0.39	0.44	0.38	0.42	0.49	0.41	0.45	0.54

Note: Source: Knox County Tennessee [73].

Table 3. Rational method runoff coefficients.

Conclusion

In summary, utilizing GIS for the identification of potential pond sites for irrigated agriculture and forestry land through watershed analysis is a valuable and effective approach for sustainable land management. By leveraging GIS techniques, including the integration of spatial data, hydrological modeling, and analysis of factors such as topography, soil type, land use, and rainfall, decision-makers can successfully pinpoint appropriate areas for constructing ponds. This study provides literature review on Identification of potential pond location and watershed and stream network analysis in the Kherlen Soum, Khentii Province using land use and DEM data. The study aimed to determine the potential pond locations using above mentioned analysis and then recommend or discover new areas for afforestation area for “Billion Tree” national movement in Kherlen Soum. During the study, we recommended and suggested 4 types of areas that cover 112,787 hectares, meaning it is roughly 28-29 percent of the entire Kherlen Soum area. If we estimate using our calculated standard for planting in one hectares, in this area we can plant approximately 80 million units of trees and bushes. To fulfill to Billion Tree National movement in Kherlen soum we could just plant all the trees and bushes in unirrigated self-growing area. Otherwise, to get a better reliable result we could plan to plant trees in all recommended areas using the suggested pond locations, Kherlen River, and old farmlands. From the example calculation of pond size, we can see that our potential pond locations and corresponding forestation areas have resources to plant an assigned amounts of plants or bushes.

In conclusion the identification of potential pond sites for irrigated agriculture and forestry land through watershed analysis using GIS offers a comprehensive and systematic approach to effective water resource management.

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B8%D0%BB%D1%81%D0%B0%D0%BD_%D1%85%D1%83%D0%B2%D1%8C%D1%81%D0
%B3%D0%B0%D0%BB

Appendices

Appendix 1. Monthly Precipitation data of Kherlen station from 2013-2022

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
2013	3.7	0.8	4.6	9	12.4	42.9	110.5	45.9	19.2	27.3	2.4	3.6
2014	0.8	2.1	0.4	2.4	37.5	93.8	80	14.7	9.5	4	1.2	4
2015	1.3	0.8	2	5.6	13.7	13	37.9	48	22.7	8.4	7.2	2.4
2016	1.6	0	1.9	2.3	22.9	48.2	26.6	22.3	86.1	16.1	9.4	2.3
2017	5	0	0.1	2.4	5.4	7.1	55.2	106.8	9.4	27.5	9.9	0.5
2018	1	1.3	1.9	4	2.9	51.7	114.6	76.6	43.7	0.1		0.9
2019	0.2	1.1		0.2	7.6	31.4	30.8	81.7	13.1	4.6	5.8	5.5
2020	0.5	2.6	0.2	0.9	30.8	93.1	90.5	127.6	22	22.1	7.7	3.5
2021	2.6	0	1.7	5.9	24.8	63.7	34.3	68.1	77.4	15.7	3.7	1.7
2022	0.5	0.9	7.1	2.6	7.4	22.4	51.8	35.8	16.2	6.5	3.8	7.5

Appendix 2. Area Calculation of Unirrigated Self-Growing Area

Unirrigated Self-Growing Area

FID	Shape *	Id	Area
0	Polygon	0	547.656589
1	Polygon	0	855.868646
2	Polygon	0	896.516028
3	Polygon	0	412.144233
4	Polygon	0	1023.305483
5	Polygon	0	3236.041496
6	Polygon	0	6850.672249
7	Polygon	0	768.650731
8	Polygon	0	2512.081173
9	Polygon	0	1102.690887
10	Polygon	0	713.714127
11	Polygon	0	199.492036
12	Polygon	0	3113.12998
13	Polygon	0	946.978662
14	Polygon	0	425.208064
15	Polygon	0	375.15756
16	Polygon	0	966.895329
17	Polygon	0	613.670674
18	Polygon	0	306.676386
19	Polygon	0	207.443379
20	Polygon	0	877.214126
21	Polygon	0	1007.601567
22	Polygon	0	890.983805
23	Polygon	0	319.151064
24	Polygon	0	434.190712
25	Polygon	0	414.882861
26	Polygon	0	4925.565967
27	Polygon	0	497.524645

28	Polygon	0	2191.716837
29	Polygon	0	141.00608
30	Polygon	0	611.042297
31	Polygon	0	21.548867
32	Polygon	0	346.894704
33	Polygon	0	259.977057
34	Polygon	0	50.66823
35	Polygon	0	775.230856
36	Polygon	0	1369.713492
37	Polygon	0	2051.495457
38	Polygon	0	695.14588
39	Polygon	0	656.372135
40	Polygon	0	1812.465085
41	Polygon	0	2633.579644
42	Polygon	0	1601.418745
43	Polygon	0	672.010181
44	Polygon	0	871.54079
45	Polygon	0	416.697646
46	Polygon	0	1160.812786
47	Polygon	0	426.008071
48	Polygon	0	158.576693
49	Polygon	0	1400.764285
50	Polygon	0	795.660633
51	Polygon	0	354.493077
52	Polygon	0	137.787577
53	Polygon	0	288.840122
54	Polygon	0	742.177605
55	Polygon	0	1434.695938
56	Polygon	0	432.713372
57	Polygon	0	1012.250391
58	Polygon	0	785.553745
59	Polygon	0	681.497787
60	Polygon	0	1023.756458
61	Polygon	0	248.958893
62	Polygon	0	548.661212
63	Polygon	0	34.468568
64	Polygon	0	46.088112
65	Polygon	0	80.734928
66	Polygon	0	218.331977
67	Polygon	0	385.893979
68	Polygon	0	232.191325

Appendix 3. Area Calculation of Irrigated Growing Area

Irragated Growing Area

FID	Shape *	Id	area
0	Polygon	0	4809.042027
1	Polygon	0	3141.894865
2	Polygon	0	1936.943203
3	Polygon	0	1432.350375
4	Polygon	0	1583.696954
5	Polygon	0	3328.30543
6	Polygon	0	3345.49474
7	Polygon	0	2915.206184
8	Polygon	0	5557.655091

Appendix 4. Area Calculation of Old Farmland for Forestation.

Area of Old Farmland

FID	Shape *	Id	Area
0	Polygon	0	2200.782129
1	Polygon	0	1564.398138
2	Polygon	0	1904.24989
3	Polygon	0	4059.486898
4	Polygon	0	2503.163444
5	Polygon	0	1468.332908

Appendix 5. Area Calculation of Kherlen River Irrigated Area

Kherlen River Irragated Area

FID	Shape *	Id	Area
0	Polygon	0	2219.852048
1	Polygon	0	3563.55826