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in **Geospatial Technologies**

A Crop Land Allocation Model

A Case Study in La Rioja, Spain

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ABSTRACT

Crop land allocation is a complex process because it requires of consideration of different factors such as ecological, environmental, economical, social, and geographical factors. Crop land allocation has been run by aligning maps with predefined crop site requirements. Geographic Information Systems (GIS) are playing an increasing role in rural planning because of their simplicity and speed of analysis of complex problems. They offer analysis for analyzing spatial and non-spatial attributes of a site. Hence, rural planning has adopted GIS directly, and in this project it has been implemented as the main tool for matching a particular crop to the most suitable areas.

La Rioja province has diverse subdivisions of agriculture. Research has found that La Rioja lacks in rural planning, as well as in crop land allocation. Therefore, crop land allocation has been implemented to find out benefits of GIS rural planning. The crop land allocation applied in La Rioja province. The application introduced in this thesis proves that GIS has an invaluable role in the development of rural planning and it opens the door for further GIS applications in this field.

KEYWORDS

GIS Applications

Crop Land Allocation

Rural Planning

Spatial Decision Making

Spatial Decision Support Systems

Geographic Information Systems

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LIST OF ACRONYMS

ED	European Datum
EDORA	European Development Opportunities for Rural Areas
EPSG	European Petroleum Survey Group
FAO	Food and Agriculture Organization
GCS	Geographic Coordinate System
GIS	Geographic Information System
LM	Land Management
RP	Rural Planning
SDDM	Spatial Data Decision Making
SQ KM	Square Kilometer
UTM	Universal Transverse Mercator

CHAPTER 1

INTRODUCTION

1.1 Background

Agriculture is one of the most ancient industries in the world. Today it is still an essential part of life because it is needed for producing food and resources for industry. Yet there is no optimal method for allocating rural areas as so to conserve the environment and natural resources, while at the same time ensuring they are economically profitable for land owners. Since the 1970's much scientific work has been conducted to formulate a particular technique to allocate specific areas for particular crop type (Riveira, I.S., Maseda, R.C., 2006).

Over the last 40 years scientists in different parts of the world have applied GIS as a tool in land-use planning (Riveira, I.S. and Maseda, R.C., 2006). Land-use planning includes diverse scientific disciplines, but it can be generalized into two main subgroups: urban and rural planning. Most work focuses on urban planning where surrounding rural areas are attached to urban zones as a part of them (Riveira, I.S., et al, 2008). Moreover, emigration, agricultural advancement and the changing nature of the rural landscape have affected rural land tenure. All these factors have deeply changed the current agricultural landscape. Exceptional up-to-date information and tools are needed in order to cover all aspects of rural activities. In addition, planning requires a special approach to specific areas due to their climate, geography, spatial and non-spatial attributes (Itturmen, M.K., Rabbinge, R., Latesteijn, H.C., 1998).

Many attempts have been made to solve land tenure management problems using GIS. For instances, Rossister (1990), De la Rosa, D., et al (1992), Ittersum (1995), Brail, R.K., et al (2001) are some examples of works that have applied GIS to agriculture.

Rural planning today depends on economic and spatial data. Consequently, spatial information systems are playing an increasing role in local government information systems for efficient management and planning of natural and human resources. Quality and availability of land information benefits local decision makers and research institutes. Range and availability dictate the accuracy and quality of the expected results. Knapp et al. (1995) have developed a theoretical model for the role of geospatial information systems in land-use planning. They focused on the effect of geospatial information on local government infrastructures and land tenure issues and its benefits in terms of time saved and quality of results.

Issues about use of spatial data in local government decision-making have been difficult to resolve because characterizing the decision-making process has been and continues to be difficult, and this was addressed in an article by Ventura et al. (2010). This article discusses difficulties in determining the role of land information in local decision-making, political, economic legal, bureaucratic, personal and social influences that have a heavy impact on planning.

Land resources are a gift of nature to maintain human life on the Earth. In terms of area, land resources are limited, therefore we must take exceptional care to use them efficiently and to be preserved them for future generations. Although, many attempts have been made, numerous areas still lack proper planning of urban and rural dwellings and other land use. The continuous increasing of world population is putting pressure on agricultural producers. These factors lead to a requirement for highly advanced techniques and quick decision-making tools. GIS is the favoured effective for rural planning.

1.2 Problem Identification

Agriculture sector will likely to play important role in human life in the next century (Sands and Marian, 2004). Rural planning in agriculture has been developed continuously. Crop land allocation is inseparable and the most important part in rural planning (Muchow and Bellamy, 1991; Kingwell, 1994; van Noordwijk et al., 1994). Since GIS was implemented in rural planning, crop land allocation has eased up decision-making in local as well region-wide. And demand for crop land allocation is increasing due to modernization of rural planning. Less attention has been applied in rural areas of La Rioja. Therfore, crop land allocation has been selected to do research in La Rioja province.

1.2 Scope

The aim of the research is to examine the study area and find suitable regions based on the available spatial data for the particular crop types. For this purpose a GIS has been extended to add support a multi-criteria decision-making system. The result shows obstacles and limitation of current spatial data, and leads us to suggestions for of future problems and opportunities in spatial information systems and the automatic decision-making process.

1.3 Research questions

This research has been carried out answers the following questions:

1. Which geospatial factors have been used to find suitable areas for a particular crop?
2. Which factors have the strongest influence?
3. As a case study, which area of La Rioja is suitable for a particular crop?

1.4 Objectives

The following research objectives have been established:

- The study of economic, social, environmental, ecological, marketing, technical aspects and geography of La Rioja Autonomous Region, Spain;
- A multi-criteria evaluation of rural areas according to spatial data sets;
- Determining of appropriate criteria for particular crop types for the sustainable development of the region.

1.5 Thesis outline

This thesis consists of four chapters and is structured as follows. Chapter 1 (Introduction) outlines the background, motivation, and research questions. The second chapter focuses on the exploration of geographic, economic and agro-ecologic conditions of the study area. Chapter three is dedicated to methodology and spatial data sets. Chapter four contributes a case analysis of La Rioja community with integration of different geospatial attributes for diverse crop types. Finally, the fifth chapter summarizes the research discussions, challenges and limitations.

CHAPTER 2

2 STUDY AREA

2.1 Introduction

La Rioja is an autonomous region of Spain located in the north of the Iberian Peninsula. It includes parts of the Ebro valley as the river flows from the northwest to the east. The region is a single province. It has no provincial council and it consists of 174 municipalities. Logroño is the capital and the population of the region is estimated at 322.000 inhabitants (INE 2011).

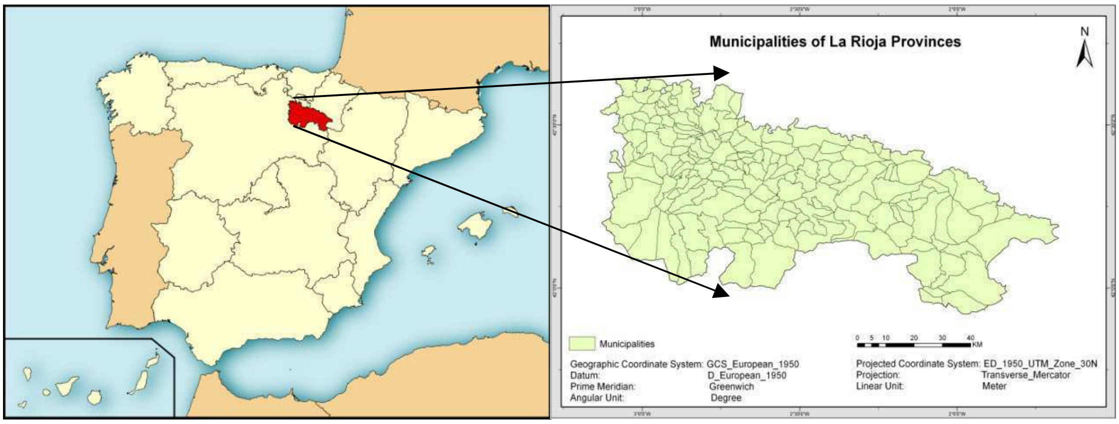

Figure 1. Location of the study area La Rioja in Spain.

Figure 1 presents geographic location of the La Rioja province in Spain. La Rioja bordered by the Basque Country in the north, the Navarre province in the northeast, Zaragoza province in the southeast and the Castilla and León community in the west and the provinces of Burgos and Soria in the south. The province lays mainly on hilly areas, so it has many different microclimates and unique environments. It is well-known for high quality wine products as well as wheat, barley, grape and many more agricultural products. The unique history and natural beauty of the province has been preserved natural beauty which makes it attractive to tourists (Maurel-Joaquín, B. and Valentí-Joan, V., 1992).

The highest areas are covered with forest and shrubs. The rich soil makes it an ideal region for planting different types of crops. Thus, for many centuries this area has attracted farmers and it has been irrigated leading to the further development of the region.

The region has a typical Mediterranean climate, with two main sectors, the mountains and the Ebro valley. The municipalities in mountainous areas depend on the cities located on the plains, which helps them to exchange products with other region. La Rioja is a small community that only has one protected natural area, the mountain range in Sierra Cebollera Natural Park.

2.2 Population

La Rioja has approximately 322.000 inhabitants in 2011 according to the municipal census and a population density of 55 inhabitants per sq km which is less than half the average population density of Spain. The population is very unevenly distributed throughout the community. There is a large disparity between the population distribution in the Ebro valley and in the mountains. The capital Logroño has about 133,000 inhabitants, which is 48% of the total population. The second largest town is Calahorra with only 20,000 inhabitants. Only three towns have more than 10,000 inhabitants: Logroño, Calahorra and Arnedo, and only four others have more than 5,000 inhabitants: Haro, Alfaro, Nájera and Santo Domingo de la Calzada. 148 of the 174 municipalities have less than 1,000 inhabitants. These number clearly indicates that La Rioja region has low population. There are 50 municipalities that do not even have 100 inhabitants (INE, 2011). Despite the concentration of most of the population in Logroño the rest of population is distributed evenly throughout the region and the majority of people live in urban areas (INE, 2011; Maurel-Joaquín and Valentí-Joan, 1992).

Throughout the twentieth century, the population of La Rioja increased at a lower rate than the rest of Spain. In recent years the population of the Ebro valley, especially Logroño, has increased and is now higher than average population density for Spain. In contrast, the mountains have been depopulated, with population densities below 10 inhabitants/sq km in the mountains of the Demanda and Cameros ranges. The mountainous regions have lost over 70% of their population due to migration.

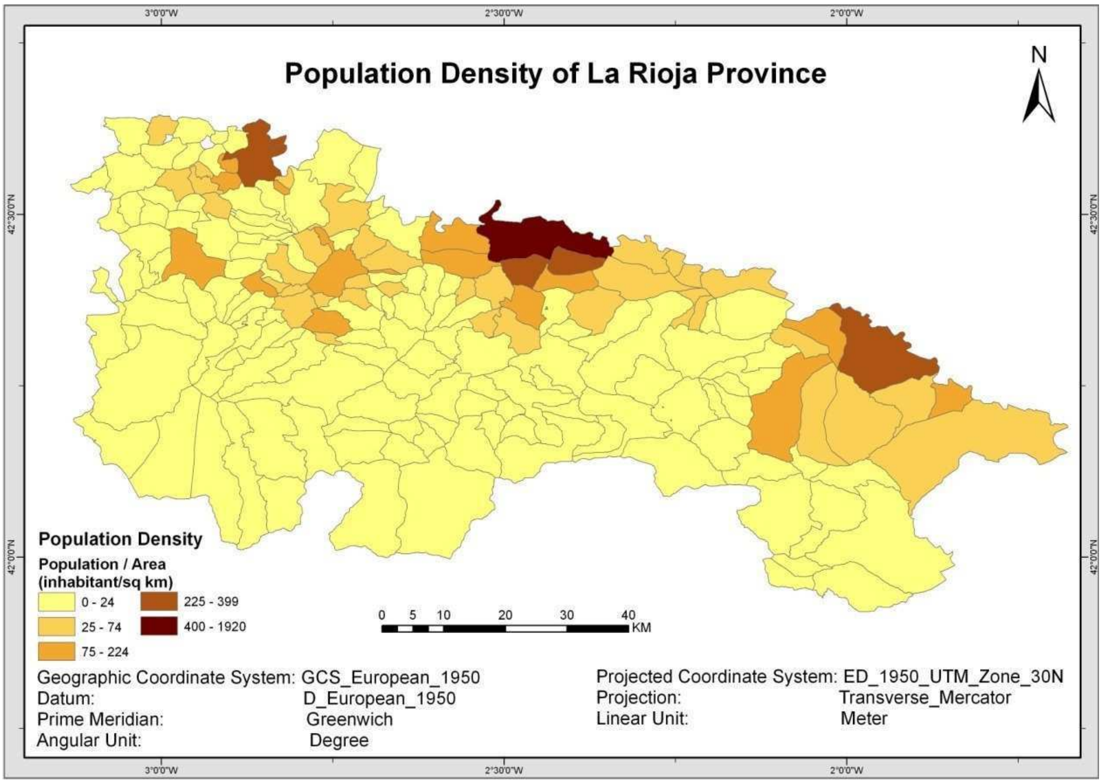

Figure 2. Population density in La Rioja region

Figure 2 introduces overall population density in the La Rioja province. Figure depicts north-east and some municipalities in west-central part of the region has more populated than other municipalities. i.e. the capital Logroño has 1920 inhabitants/ sq km, Calahorra and Arnedo have 266 and 169 respectively. Also, figure indicates that population in southern part of the La Rioja distributed evenly.

This migration has had three main destinations, with emigration to Logroño, some other parts of Spain and also to foreign countries. The nineteenth century was a period of emigration mostly to America. In the 1950's and 1960's destinations were the Basque Country, Navarra, Madrid and Catalonia in Spain, as well as France and Germany. However from the 1970's onward migration slowed due to new development opportunities offered by improved transport and connections with the Basque Country, Aragon and Catalonia. Recently La Rioja's economy was growing faster than the average for Spain, at 4% versus 3%. Due to this increase there is no doubt that La Rioja has become a net recipient of immigrants, but is not an outstanding destination because of its small overall population (Maurel-Joaquín and Valentí-Joan, 1992).

The birth and death rates have followed the general cycle of demographic transition change for the whole of Spain. However, since 1960's the birth rate has been just below the Spanish average, due to migration, which has affected the population of reproductive age. Since the 1960's, the aging of the population has slightly increased the mortality rates. However, immigration to the region will probably continue to increase the population in the coming years (Manuel and Sabarís, 1978).

2.3 Relief

La Rioja province consists of mountainous areas (with the mountains of the Iberian in the south, and the Basque-Cantabrian Range in the north) and on the north plains of the Ebro valley. The varied landscape has given a wide variety of ecological conditions. The highest altitudes are the peaks of Monte San Lorenzo (2262 m) and La Mesa (2168 m) in the west, Urbión (2228 m) in the north-west, and San Millán (2131 m) in the central west (Manuel and Sabarís, 1978).

The mountains in La Rioja make up part of the Iberian mountain range: Demanda, Urbión, Cebollera and Cameros Ranges, all of which are shared with Burgos and Soria. The Demanda Range is deeply fractured, which is invaluable in protecting soil, for holding moisture and nutrients, preventing soil erosion. The Demanda Range has synclinal valley, which the Canales River flows through and which connects La Rioja to the Burgos. Urbión, The Demanda Range is much diversified in terms of agricultural production. The Urbion Range lies in the East, dividing Duero and Ebro, and is an intensively folded mountain range. It differs from the others because of its dynamic peaks in typical alpine relief. The Cebollera and Comeros Ranges lie eastward with an altitude gradually decline to the east (Manuel and Sabarís, 1978).

The Ebro basin forms the central part of the community. The basin occupied by marls and clays, with a typical tableland relief. There is a gradation in the size of the sedimentary deposits, clays and loams, which are smaller in the center of the Ebro basin. There are gypsum and salts which emerge in the form of diapers (Manuel, 1978; Maurel-Joaquín and Valentí-Joan, 1992; Ridruejo-Clemente, 1996).

2.4 Climate

La Rioja's climate is Mediterranean with great microclimate diversity. The most dynamic aspect of the climate is the main polar front, which discharges its humid air, and the Azores anticyclone. Thermal anticyclones appear in winter in the Ebro, valley giving the region cold, dry climate, and causing frequent fogs in spring and autumn.

Since La Rioja is located far from the Bay of Biscay, the Föhn effect results in the region being dry and warm, but not excessively so. Lower mountainous terrain in the northeastern part of the province results in frequent cloudy days in comparison to other parts of Spain. The mountains cause the climate, making it warmer and drier in the north than in the high altitudes in the south.

Precipitation is irregular across La Rioja, as there is clear north-south gradient. The rainy seasons are during winter and spring, because maritime polar air masses bring polar fronts. The Azores anticyclone dominates in summer and continues to influence the weather in autumn. The distance from the sea and the barrier effects of the Cantabrian Mountains result in cold rainfall. Along the course of the Ebro downstream from Logroño, precipitation is low until Alfaro, where it is around at 400-500 mm per year. However, in the mountains rainfall increases gradually reaching 1000 mm and even 1100 mm at the highest altitudes. The highest rainfall occurs in the Demanda and Cameros Ranges, where the dry seasons are spring and summer. The fall is the second rainiest period in the Ebro valley. In the winter months, rainfall decreases along the Ebro River to Haro town but more than doubles in and around the mountains. The number of dry months decreases steadily going up the mountains (Manuel, 1978; Maurel-Joaquín and Valentí-Joan, 1992).

The temperature pattern has a very sharp gradient and it is similar to the precipitation pattern. The temperature decreases from the Ebro valley toward the southern mountains. There are also steady differences in temperature along the valleys and mountains, which are warmer on the north and cooler towards the south. The average annual temperature in the Ebro valley is 12º C, whereas in the southern mountains it is 4º C. This implies that much of the precipitation in the Demanda and Cameros mountains is in the form of snow. The coldest month is January and the hottest is July. In January temperatures can fall below 0º C throughout the region. The summer is cool during the day and cooler at night (Manuel, 1978; Maurel-Joaquín and Valentí-Joan, 1992).

2.5 Water sources

The main river of the province is the Ebro River, which forms the backbone of the region, and all the other rivers flow into it. The Ebro rises in Fontibre (Cantabria) and flows to near Tortosa (Tarragona). It enters La Rioja after passing through Las Conchas de Haro. From its origins near the top of the mountain, it flows through the following towns: Haro, Logroño, Calahorra and Alfaro. It is a typical Mediterranean river causing floods in summer and swelling raising in quantity in spring when snow melts producing a greater volume of water. Sometimes this causes soil erosion near the river banks. On the other hand, La Rioja municipalities are well organized in terms of drainage systems especially in Alhama, Cidacos, Tiron, Leza, Najerilla and Iregua (Manuel, 1978).

The Tiron River rises in the province of Burgos, on the northern slope of the Demanda Range. It has numerous streams, but in La Rioja, the most important is the Oja River. The Oja River rises in the mountains of the Demanda Range near Logroño, passes through Santo Domingo de la Calzada and joins the Tiron just before the point where the Tiron joins to the Ebro River in Haro.

The Najerilla River rises on the north side of Urbión Range on the opposite side to the Duero River. It passes by Nájera before joining into the Ebro River and it provides the most water as the largest source of the Ebro in La Rioja.

There are 3 more main rivers. The Iregua River starts at the top of the Cebollera Range. The Leza River rises in the Cameros Range. The Alhama River starts in the Contadero Pass (Soria). All rivers flow into the Ebro River (Manuel, 1978; Maurel-Joaquín and Valentí-Joan, 1992; Ridruejo-Clemente, 1996).

2.6 Agriculture and Forestry

La Rioja has a developed economy with well developed tertiary sector, but the most significant feature is the high rate of mechanization of agricultural tasks, especially those related to the production of wine and vegetables.

Despite its small size and population, the region is situated in a prominent position in terms of economic growth, with a per capita income well above the national average and a higher employment rate.

In La Rioja, the productivity rate of agriculture in the regional economy is higher than the Spanish average. It has grown in recent years due to the importance of the wine sector and the national leadership of this region in crops such as wheat, barley, cauliflower and thyme. In addition, the region is supported by the food industry with its major presence in the region providing important benefits by increasing the added value of products sold. It is based on a mechanized agriculture and market-oriented production. However, ownership structures make holdings too small, and the owners have to worry about aging because the younger generation is not willing to continue farming. Land consolidation has had little impact on La Rioja, and farms with irrigated orchards and vineyards are less concentrated than in other areas. The concentration which has occurred is mainly due to the remaining residents purchasing land abandoned by emigrants (Manuel, 1978; Maurel-Joaquín and Valentí-Joan, 1992).

Agricultural industry accounts for 83% of the total economy, and wine and its derivatives alone account for 49%. Livestock is 14% of the total and forestry is 3%. The success of the wine industry is due to institutionally support and the creation of a designation of origin that guarantees high product quality. Its high profitability has led to the appearance of small vineyards that are run by owner on a part-time basis. Livestock and forestry are the main industries in the mountainous areas, where there also many abandoned farms due to population decline, whereas agriculture is concentrated in the lower lying regions (Maurel-Joaquín and Valentí-Joan, 1992).

The Ebro Valley has large share of cultivated area, about 161,000 hectares, whereas the mountainous area has more than 100,000 hectares of grassland, which is used almost is devoted exclusively for livestock production. Agriculture and livestock are diverse across the province. The high and low regions La Rioja have very distinct types of crops. In the high areas of La Rioja, forest and shrubs predominate. Low lying areas of La Rioja specialize in orchards and vineyards, and also in vegetable and cereals. The difference can be seen between mountain farms with natural rainfall, and the irrigated regions on the plains. This specialization in irrigation of the lower Rioja is due to the construction in the early twentieth century of Lodosa Canal. The main production includes wheat, barley, and thyme. Horticulture in La Rioja is beginning to undergo a process of modernization with crop under plastic but only in some regions (Manuel, 1978; Maurel-Joaquín and Valentí-Joan, 1992).

2.7 Vegetation and natural areas

The contrast between the Ebro valley and the mountains of the Iberian mountains give the region of La Rioja a considerable ecological variety. However, this region has been a heavily exploited both in the valley for agriculture and the mountains for grazing, and there has only been some replanting with native species. Thus, the native forest patches are very small and today the largest areas can be found in the high valleys of the Oja, Iregua and Najerilla Rivers. The native forest has Mediterranean forest and shrub species (Manuel, 1978).

The basal layer of La Rioja is formed by the valley of the Ebro, up to 600-750 meters in the mountains. A stage of natural degradation of Mediterranean forests occurs here due to the dry climate and temperature. However, human effort has practically overcome this hindrance and planted different types of vegetation (Manuel, 1978).

Higher areas of La Rioja are covered with pine forests and have suffered from depopulation by rapidly growing non-native trees. In the alpine zone, above 1,800 m we find the alpine meadow, with pine and beech in groves. This area was used for summer pasture from the Middle Ages or earlier until mid-twentieth century (Ridruejo-Clemente, 1996).

CHAPTER 3

3 METHODOLOGY AND DATA SETS

Agriculture has a large variety of components: crop systems, water management, transportation networks, livestock, and many more. One of the main products of agriculture is recognized as crop products. In order to get the expected beneficial result, a crop system needs to be managed efficiently, based on crop land allocation criteria. Crop allocation depends on many factors and conditions: starting from the biological context of soil to current market conditions and stability. The current method of a crop land allocation principally focuses on placing or replacing crops in suitable areas. We assume rural planning is closely tied to spatial data and its attributes. Therefore an analysis has been undertaken based on the geographical attributes of the study area.

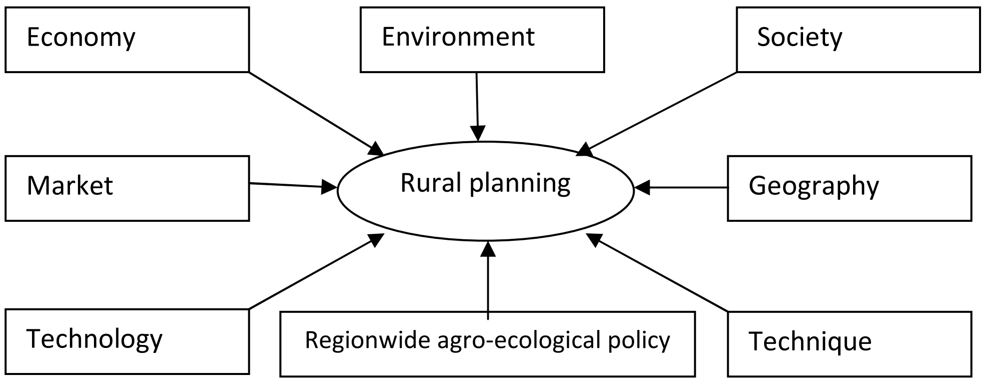

Figure 3. Impact factors in rural planning

Figure 3 presents possible impact factors on rural planning. It shows how many diverse issues contribute to the management of rural areas.

The analysis has been carried out in two stages. In the first stage, articles related to site suitability, analysis, rural planning, crop-types and their requirements, crop-land area optimization, economic and environmental assessment have been studied and summarized. In order to do research in this field a tremendous amount of data and effort is needed to achieve accurate results. The second stage consists of analysis of a case study. As a result, a site suitability maps for crops have been generated.

Each crop type has unique requirements in terms of slope, climate, thermal, precipitation, water availability, and other geospatial attributes for plausible growth in a particular area. Searching for suitable areas enables land-use planning on the basis of assessment of geophysical resources, and their spatial and non-spatial attributes. This type of generalization provides a standard framework for placing crops, taking into account relevant characteristics of geography, climate, soil quality, and others. Spatial crop allocation applies previously assumed reasonable site crop requirements of prevailing climate, soil and terrain resources, under assumed levels of inputs and management conditions (You et al., 2007).

The following steps have been followed in the search for suitable sites. First, based on predefined requirements and the standard framework, minimum to maximum plausible borders for a particular crop type have been extracted. Second, using a similar technique applied to annual temperature and precipitation, regions have been clipped. Third, different geo-environmental conditions have been overlaid and extracted. Fourth, the result defining allocated crop areas within the community has been mapped.

3.1 Data collection

The spatial data sets have been retrieved from *www.iderioja.larioja.org*. From these data sets, the following information was used: hydrography, temperature, precipitation, elevation (contour lines), municipalities.

3.2 Preprocessing

It is important to check spatial data before processing to avoid any mismatching among data sets. For this purpose, the spatial data sets have been studied carefully in regard to the geographic and projected coordinate system. All spatial data have been reprojected to European Datum 1950, Universal Transverse Mercator Zone 30 North (ED_1950_UTM_Zone_30N).

Table 1. List of spatial data sets

	Geographic coordinate system	Spatial resolution, meter	Notes	Downloaded date	Data type
Elevation	UTM ED50 zone 30N: EPSG: 23030	500 000	Elevation represented in contour lines	15.09.2010	Vector
Hydrography	UTM ED50 zone 30N: EPSG: 23030	500 000	Main water sources mapped in line feature format	15.09.2010	Vector
Temperature	UTM ED50 zone 30N: EPSG: 23030	500 000	Annual average temperature across the region	15.09.2010	Vector
Precipitation	UTM ED50 zone 30N: EPSG: 23030	500 000	Annual average temperature	15.09.2010	Vector
Municipalities	UTM ED50 zone 30N: EPSG: 23030	500 000	174 municipalities	15.09.2010	Vector

3.3 Data Sets

Elevation has been taken to calculate slope of the region. Contour lines are at 100 meter interval.

3.3.1 Slope

Elevation data (contour lines) have been converted from shapefile to raster format in order to express terrain. Figure 4 illustrates generated terrain situations in the community from elevation data. Because of no border of contour lines figure automatically draws rectangular bound of the region with available contour area. Then the slope has been calculated and clipped to cover only the study area. Red regions present highest peak points of mountain whereas green one indicates plain areas without or less slope. Since elevation (raster) data in float format, it has been converted to integer format in order to ease for further classification of the slope.

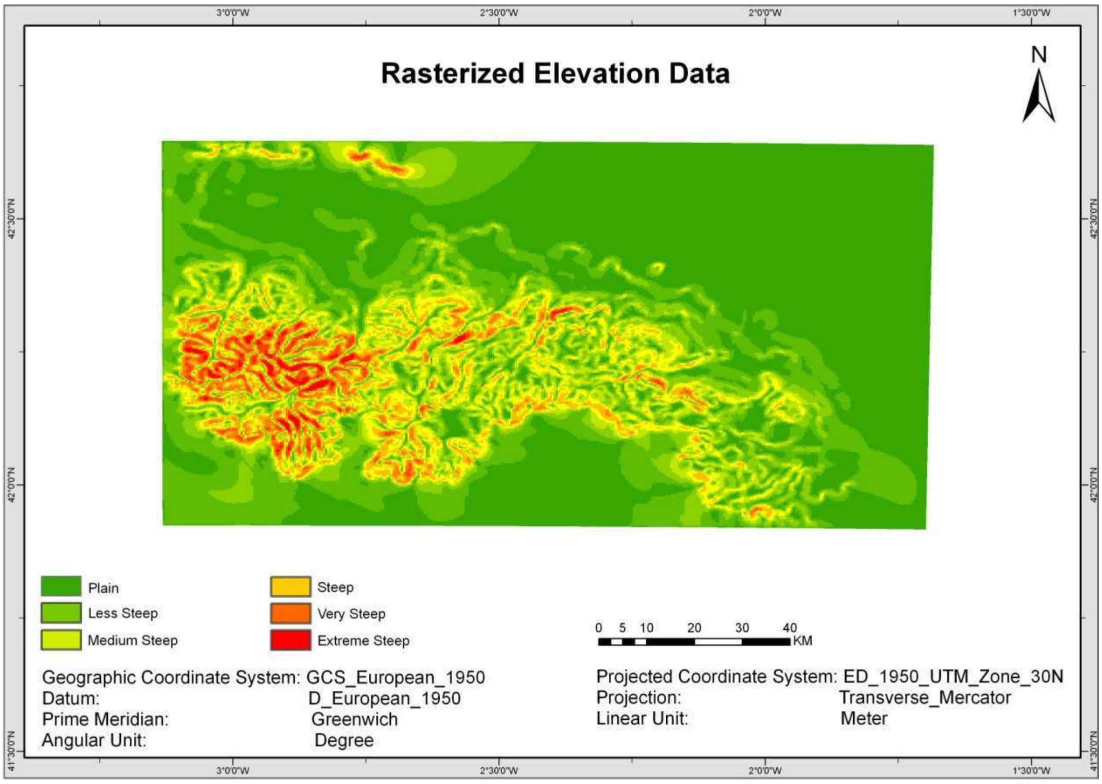

Figure 4. Rasterized elevation data

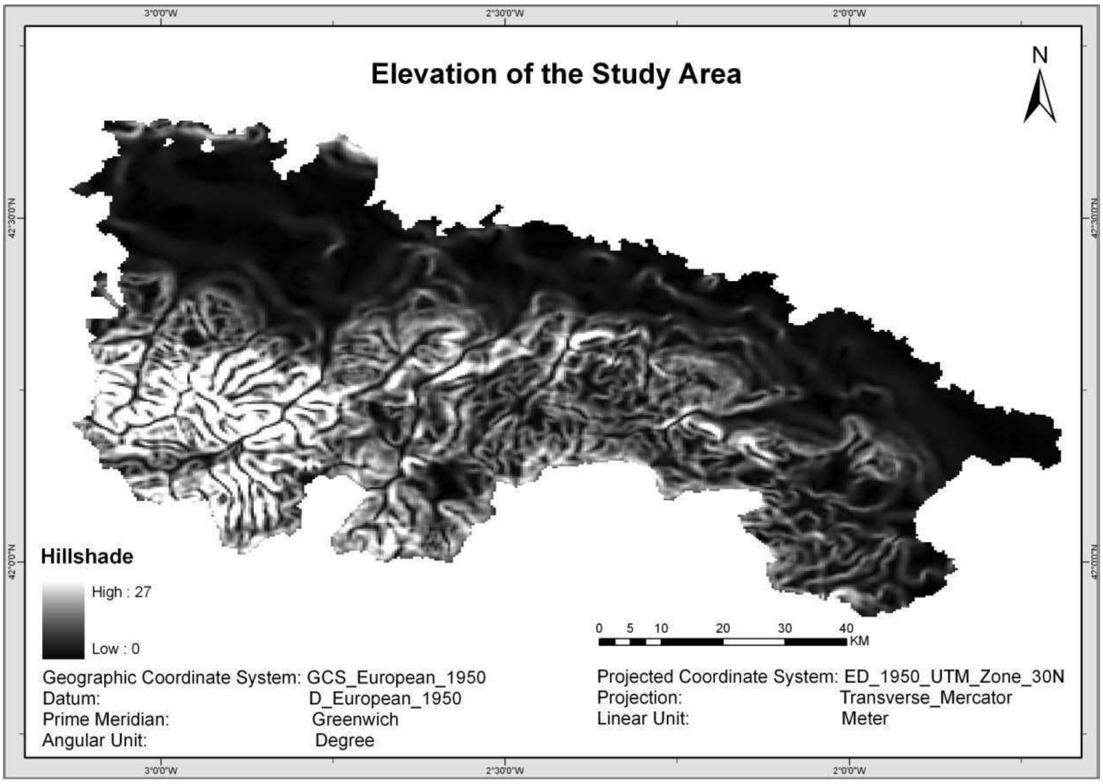

Figure 5. Elevation of the study area

Figure 5 shows cropped elevation data and it is converted to integer. The black to white contrast represents the relief with light and shadow. The slope has been classified into 51 classes from least to extreme steep areas. Slope of region ranges from the lowest 0% to highest 51% slopes. It needs to take into consideration that the province has no slope of 50% areas. Hence, in total there are 51 classes instead of 52. The elevation data is evidence that La Rioja community has a wide variety of elevation distributed over the whole region. White regions illustrate peak points of the area.

In order for simplification purpose, each 10% have been grouped resulting in total 5 classes. Therefore, figure 6 has been dissolved to obtain 5 classes as follow.

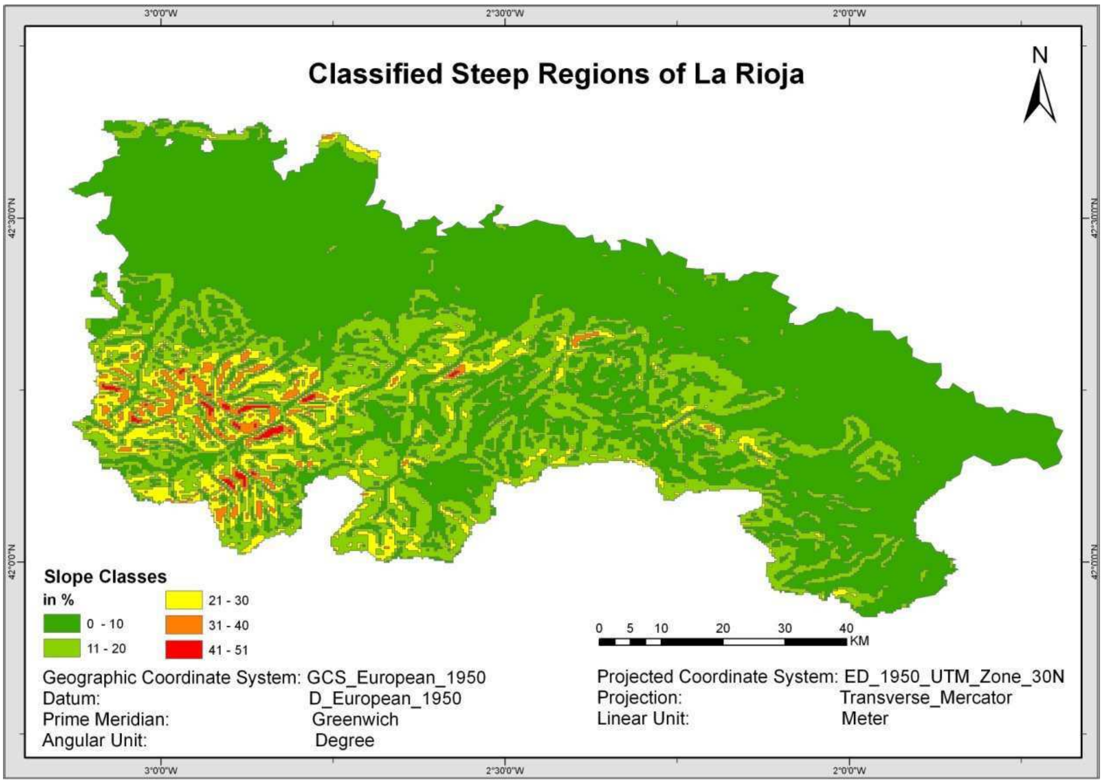

Figure 6. Classified steep regions of La Rioja

The figure 6 shows that the southern areas are very steep. Because of sloppiness, soil cannot hold seeds and it might create landslides. However, the figure shows that the study area has quite appropriate regions for planting crops that can be harvested by mechanical force using a tractor, etc.

Table 2. Slope angles and areas of respective undulation

ID	Shape	Slope angle, %	Area, sq km	Area in %
1	Polygon	0-5	2385,68	47,35
2	Polygon	6-10	892,66	17,72
3	Polygon	11-15	805,30	15,98
4	Polygon	16-20	464,73	9,22
5	Polygon	21-25	244,46	4,85
6	Polygon	26-30	134,03	2,66
7	Polygon	31-35	68,25	1,35
8	Polygon	36-40	27,50	0,55
9	Polygon	41-45	12,57	0,25
10	Polygon	46-51	2,96	0,06
		0-51	5038,14	100

The table provides information that about 90% of the study area has a slope lower than 20%. And only 2% of the whole region is extremely precipitous with slopes ranging from 31 to 51%.

3.4.2 Temperature

Annual average temperature has been taken and prepared as follow. Each region has colored red the highest and blue the lowest temperature.

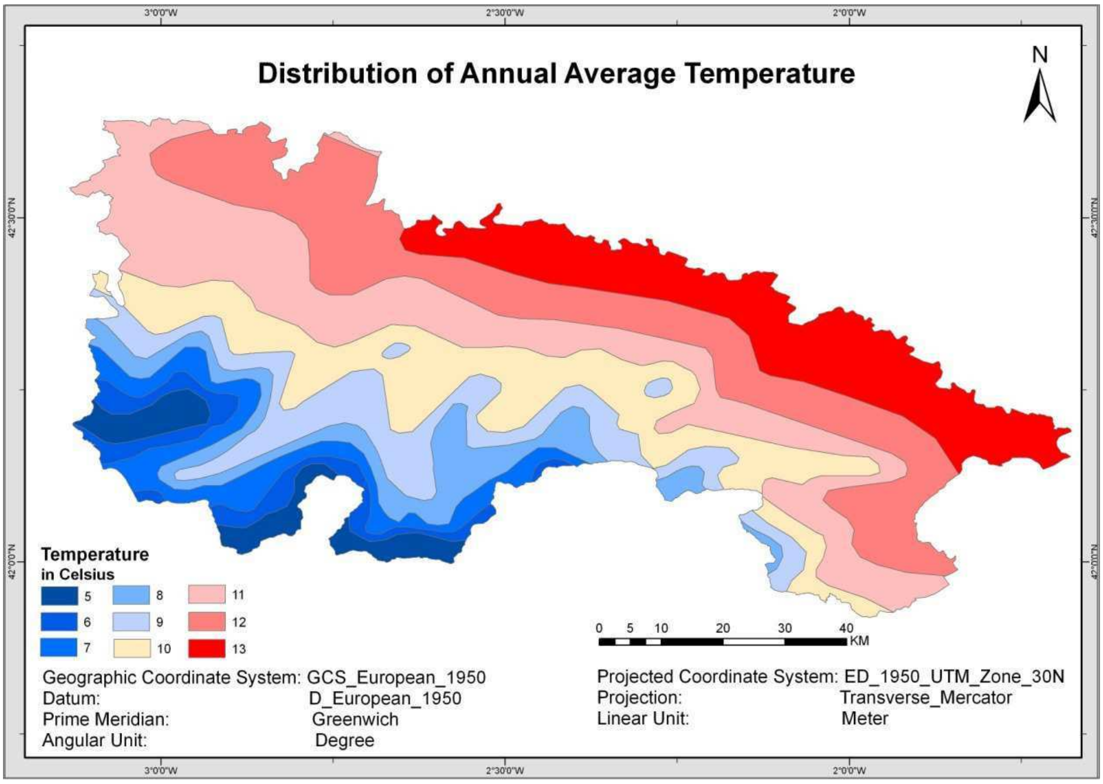

Figure 7. Distribution of annual average temperature

Figure 7 demonstrates that the average temperature varies over the community. In view of the fact that the mountainous area is located in the south of the community, the average temperature decreases accordingly from north to south. The red regions have the highest average temperature while the blue ones have the lowest. The annual average temperature ranges from 5^0C to 13^0C.

3.4.3 Precipitation

Annual average precipitation has been colored for easy interpretation.

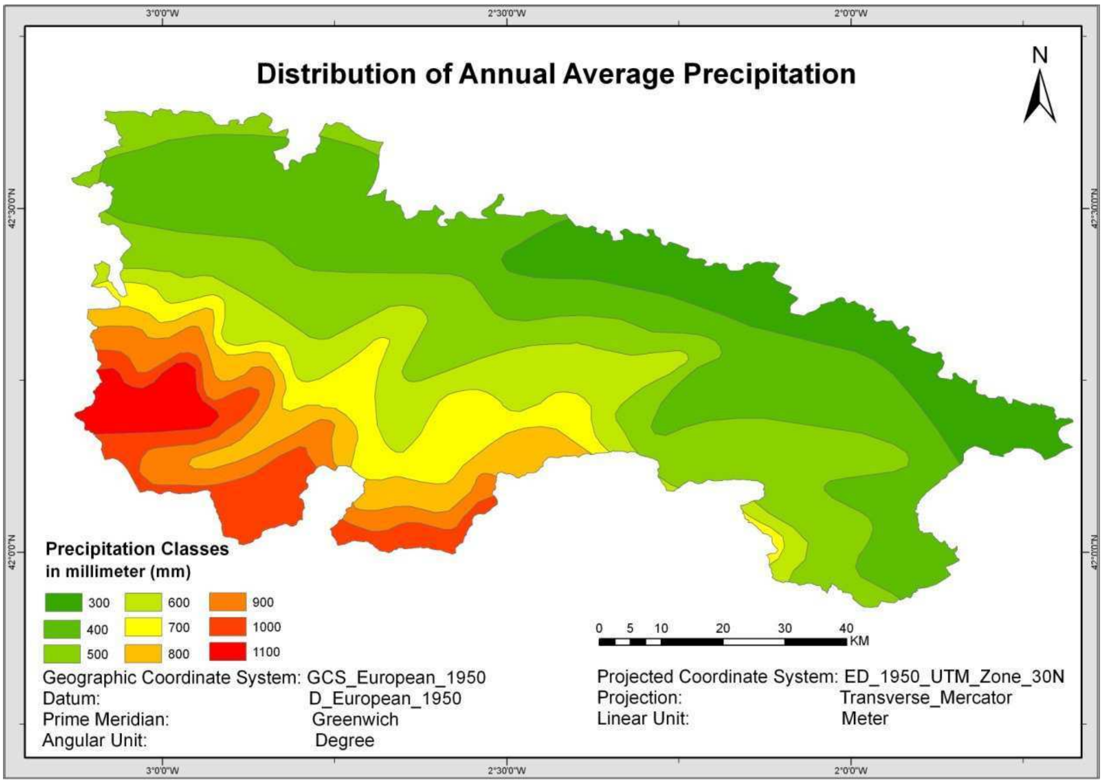

Figure 8. Annual average precipitation

The figure 8 shows the distribution of precipitation of the study area. Green shows low rainfall, whereas red depicts high rainfall zones. The darkest green zone represents precipitation of 300 mm and the red zone precipitation of 1100 mm. Overall, high mountains caused higher and plain area depicts lower precipitation. It shows some correlation with temperature, totally.

3.4.4 Hydrography

Hudrography data set have visualized to show locations of the river in the La Rioja.

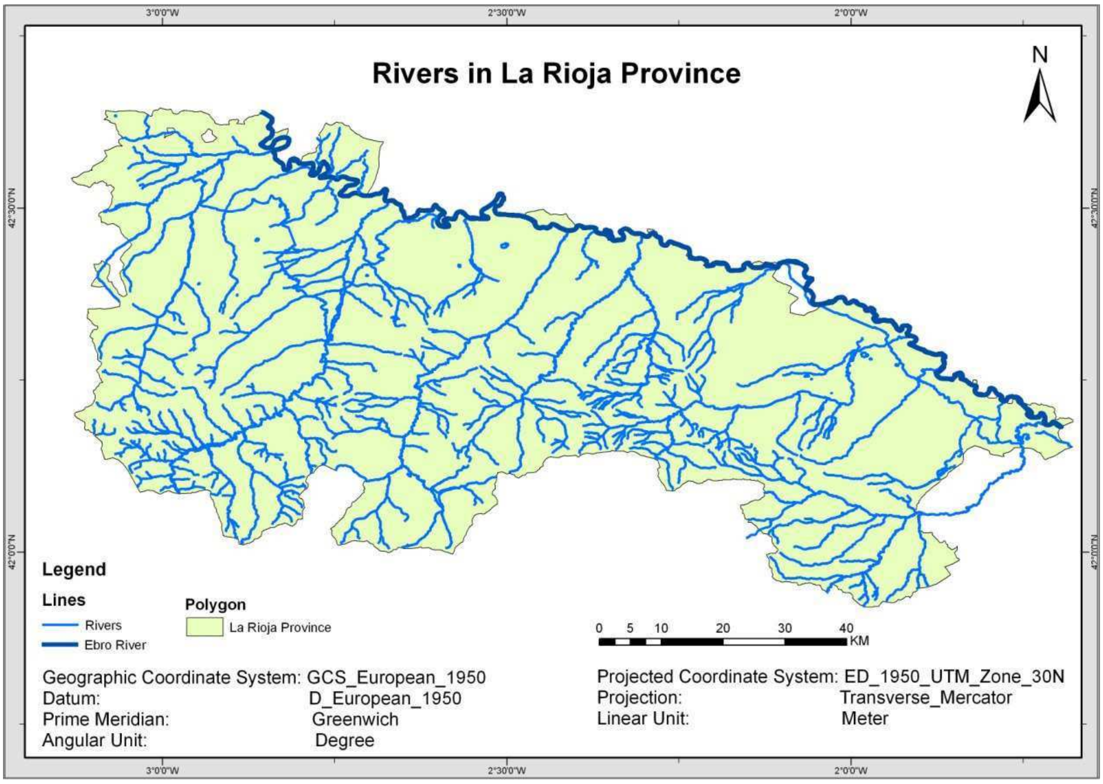

Figure 9. Rivers in La Rioja province

Figure 9 presents that the rivers rise at the top of the mountains and are filled by melting snow and ice. All major rivers feed their water into the Ebro River, which runs from the northwest side of the community to the east. The image demonstrates how the region is rich in water resources which are the backbone of agriculture and crop allocation.

CHAPTER 4

4 Suitability Analysis

4.1 Case Study

Geographic information system can analyze various data sets integrating spatial and non-spatial information to observe situation and suggest possible turning points for further development of a region. They provide better means than just representing situation in numbers. It is easier to understand local, region or state wide situations. Since most information has spatial expression, it allows presenting many phenomena as maps.

Planning mainly depends on the quality of information for rural planning. GIS has become a major tool and has been implemented for crop land allocation. Hence, quality and precision of spatial data are fundamental to analyze the factor variation for vineyard management. ArcGIS has sufficient tools to bring this idea into reality. A simple application of spatial information system does not yet appear to have been developed for vineyards (Robinson et al., 1999).

La Rioja is leading in producing agricultural products with in Spain. There are many crops to study. However, 5 main crops have been chosen in this research. There are grape, wheat, potato, barley, and thyme.

In the La Rioja community, different types of grape crops are grown, namely Tempranillo, Mazuelo, Garnacha, Graciano, Viura, Malvasia and Garnacha Blanca (White Garnacha). Most areas of the community are covered with Tempranillo because of optimal physical, climatic and geographic condition in the La Rioja community. Tempranillo is one of the noble grapes and its wines are of exceptional quality. Further on, Tempranillo will be replaced by grape for simplification and the work will be based only on Tempranillo grape crop. All criteria are founded on Tempranillo's agroecological requirements.

Smith and Whigham (1999) have discussed the factors that directly and indirectly affect viticulture and its development:

- Finding suitable areas for specific management. For instance, design of land plots for further optimum results;
- Measuring and monitoring results;
- Targeting specific and controllable factors;
- Analysis of results from periodically monitoring of viticulture;
- Selection of grapes at harvest, based on spatial similarities.

4.2 Grape

Stanton (2010) discusses and suggests to plant grapes on hillside to drain grape roots from water, since water runs downstream, and keeping fresh water throughout season. Another advantage is to control the crop expose to heat or cold – based on slope orientation. During winter hillside protects from frost damage and prevents plants from wilting in extreme hot weather.

4.2.1 Slope

Wolf and Boyer (2009) add more precision to the issue. Hillside should face eastwards thus grape plots would have some sunshine during daytime. Vineyard needs to be exposed to direct sunlight in the morning; eastern exposures are probably optimal (Gladstones, 1992). The morning sunshine advances the start of temperature and light dependent photosynthesis. This may prevent diseases because of the rapid drying of morning dew and rain. Eastern slopes also tend to be more sheltered from the hot afternoon sun, which might be of some benefit to retain volatile aromatic compounds in fruit. However, this aspect is a small part of slope characteristics and therefore, it does not influence crop growth much. The article argues that the optimal slope for grape crop ranges from 0 to 15%. On the other hand a higher slope requires more effort to keep and harvest, as a consequence it is expensive to operate equipment on steep slopes, which results in inconvenient transportation and worker movement. As a result, it may cause more cost to the land owner. Slope requirement for grape has been applied and extracted from slope data to find out suitable regions with slope of 15% and less.

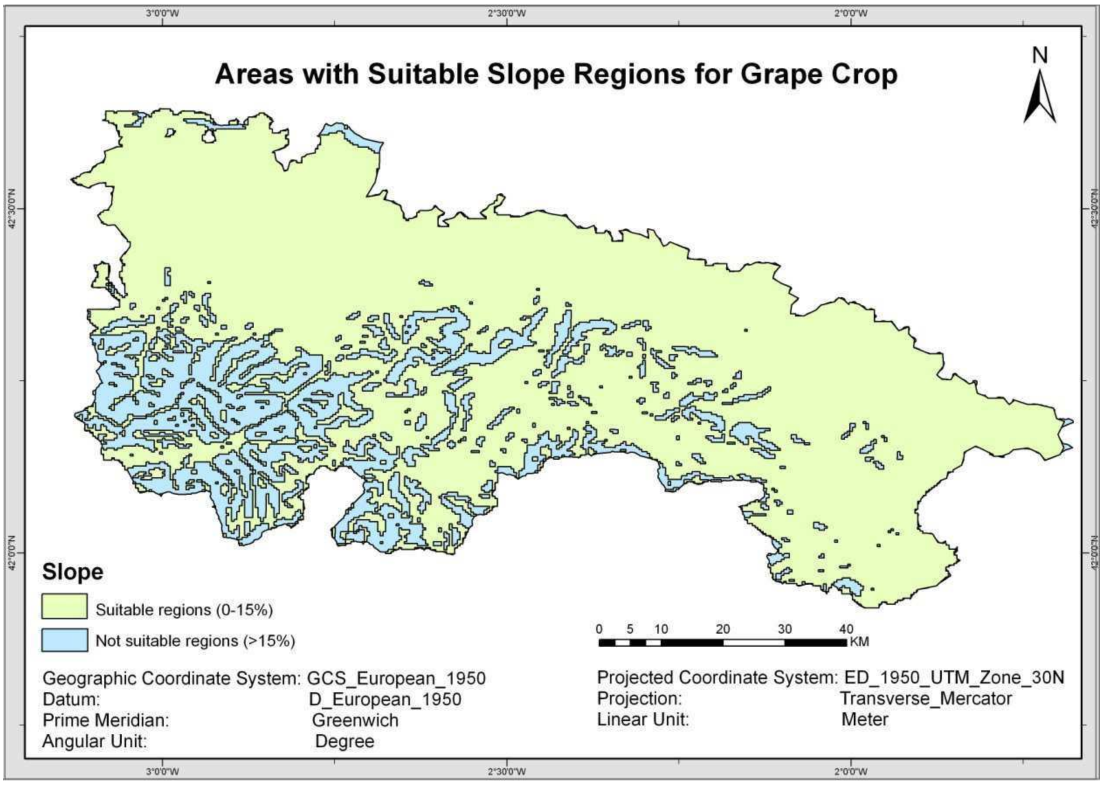

Figure 10. Suitable slope regions for grape crop

Figure 10 shows 4084 sq km for planting grape in terms of incline. The figure indicates central, south and north area, and mostly south western part roughly inappropriate for growth of grape in terms of slope.

4.2.2 Temperature

Mostly north west part of the region and some central area has higher slopes. Cooperative and Mutual Site (2001) says grape crop is very sensitive to temperature. Hence, to keep fruitfulness of crop, it is needed to be careful on temperature throughout year. The lowest temperature that can be resisted in winter by the grape crop is -2^0 Celsius. Newly planted grape needs at least -1^0 Celsius. Following these rules prevents loss of production in the future. However, optimal temperature for growth is over 10^0 Celsius and for good fruit production temperatures between 18 and 25^0 Celsius are preferable. The article argues for having an average yearly temperature not lower than 9^0 Celsius.

Based on Cooperative and Mutual Site (2001), annual average temperature ranging from 9^0 to 13^0 has been cropped from temperature data set.

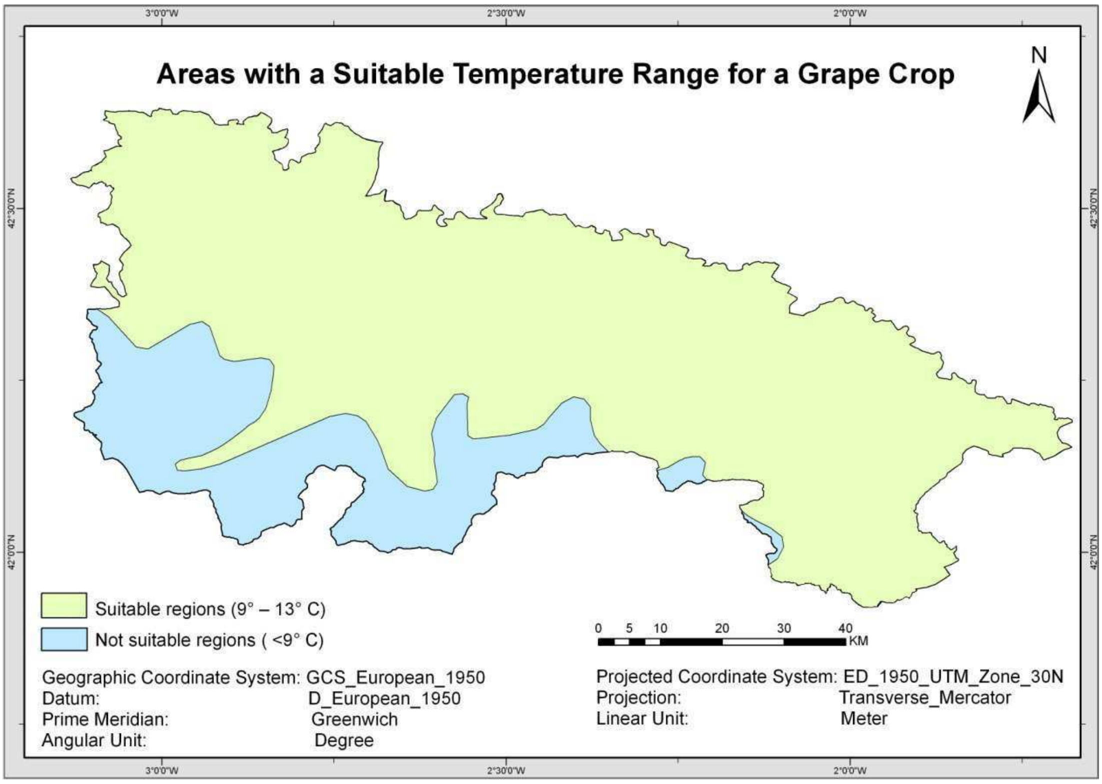

Figure 11. Areas with a suitable temperature range for grape crop

Figure 11 presents suitable temperature range areas for group crop. 4033,45 sq km (80%) area is found suitable for the growth of grape in terms of annual average temperature. Suitable area is evenly distributed. Because of high mountains in the south, highlands have low annual temperature. It is resulted in considering those regions as unsuitable. Summary of the suitable area is given in the following table 3.

Table 3. Suitable temperature range for grape crop

FID	Shape	Average temperature	Area, sq km
1	Polygon	9	453,10
2	Polygon	9	5,71
3	Polygon	9	7,88
4	Polygon	9	34,83
5	Polygon	10	725,17
6	Polygon	10	4,90
7	Polygon	10	61,98
8	Polygon	11	1019,20
9	Polygon	11	5,31
10	Polygon	12	989,01
11	Polygon	13	726,36
	Total		4033,45

The table 3 shows that 4033,45 sq km or 80% of total area is plausible to plant a grape crop. Table indicates that temperature of 11^0-13^0 has largest share and thus, La Rioja province has good condition for the growth of grape crop.

4.2.3 Precipitation

Cooperative and Mutual Site (2001) argued that most favorable precipitation range for grape is between 300 and 600 mm available during the vegetative stage, taking into account losses due to evaporation, runoff and percolation. Therefore, areas with annual average precipitation of from 300 to 600 mm have been clipped to extract suitable regions according to Cooperative and Mutual Site. Numbers indicate that grape is not much tolerant against high precipitation. However, figure 12 shows more half of regions is favorable for planting grape.

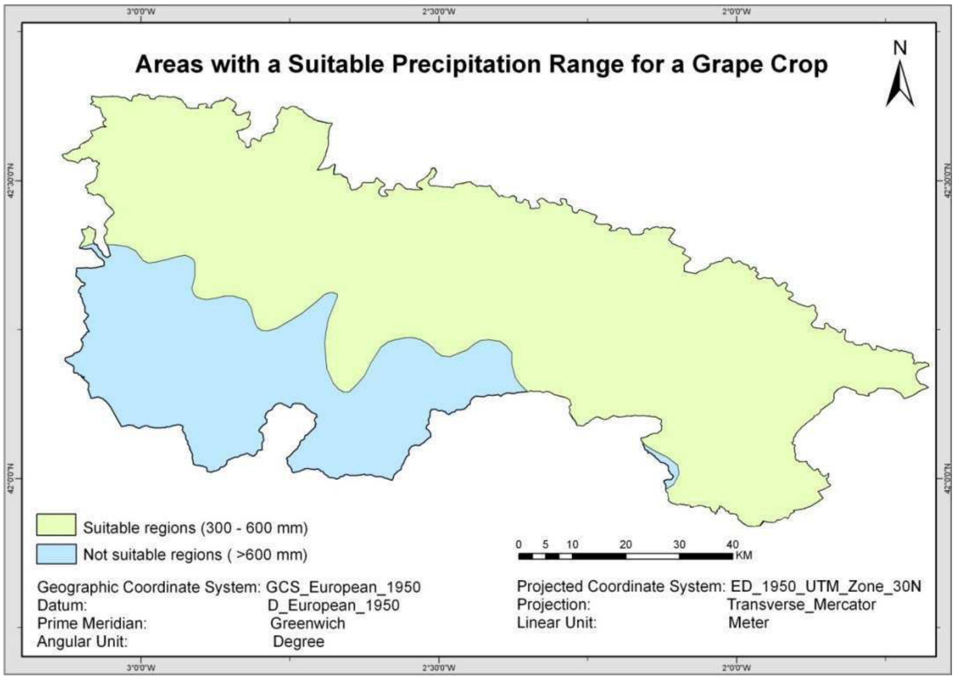

Figure 12. Areas with a suitable precipitation range for grape crop

Figure 12 illustrates suitable regions for grape in terms of rainfall. In total, suitable areas for grape have been found to be 3673,38 sq km. Suitable regions are mainly present in the north and north-east part of the La Rioja region.

4.2.4 Result map

In order to find suitable areas based on criteria, all plausible region on a particular conditions have been clipped and following figure have been generated.

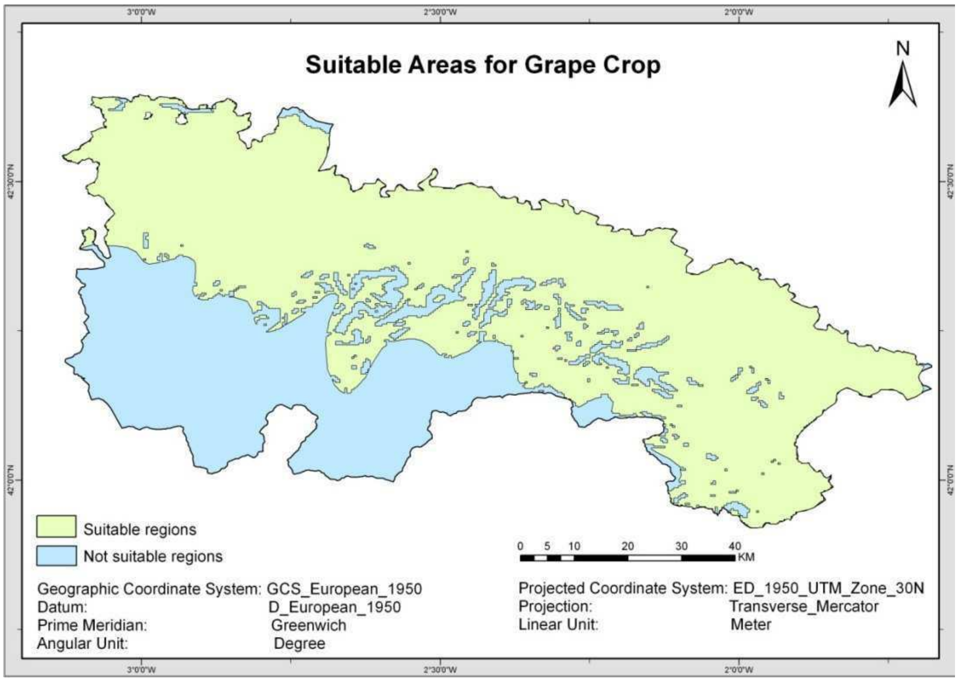

Figure 13. Suitable areas for grape crop

Figure 13 illustrates suitable areas for grape crop in terms of all criteria that have been studied. The suitable lands have been found to be 3369,69 sq km. The result covers almost three fourth of the community.

4.3 Wheat

Wheat is one of the most consumed agricultural product. It is the third most produced cereal after maize and rice. World production of wheat is about 600 million tons each year (FAO, 2009). Spain produce 6 million tons, slightly increasing every year in the last 10 years (FAO, 2009). Among provinces of Spain, La Rioja has quite suitable agricultural conditions. Ghaffari et al. have studied wheat and climate integration in the Karkheh region. The region has similar geographic and climate attributes within study area. The optimal geophysical condition was extracted from an article to find suitable areas for wheat crop.

4.3.1 Slope

Slopes greatly affect land suitability since they only dictate indirectly whether the wheat seed is able to grow under sloppy areas. The site suitability was assessed according to the elevation characteristics of the region. The topography of the region dictates that extremely sloppy areas which covers south part of LA Rioja are unsuitable for wheat crop plantation. However, a slope of up to 20% is suitable for growth and it is about 90% or 4548.367 sq km of the study area. Slope data has been clipped with criteria of 20 % to extract plausible regions for wheat crop.

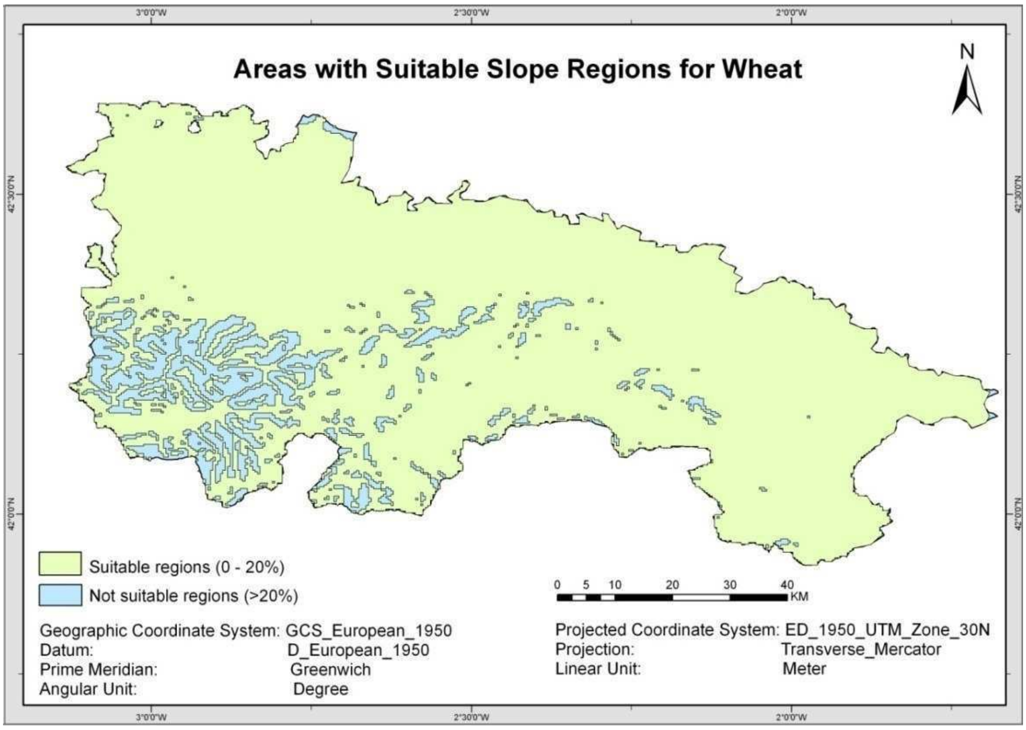

Figure 14. Areas with a suitable slope regions for wheat crop

Figure 14 shows that unsuitable areas are located on the southwestern part of the region and some spots around the central part. Elevation alone does not affect land suitability since the whole study area is highly or moderately suitable for this crop. On the other hand, average precipitation is the main source for growth of the crop. Since La Rioja lacks irrigation equipments in most municipalities, the region completely relies on rainfall during cropping time.

4.3.2 Temperature

Another climatic condition is temperature which is unevenly distributed throughout the region. Since the Ebro valley has a higher temperature, the northern part is appropriate to allocate wheat crops with annual average range of 11^0 and 13^0 Celsius (Ghaffari et al.). Annual average temperature data has been cropped ranging from 11^0 and 13^0 C from precipitation data.

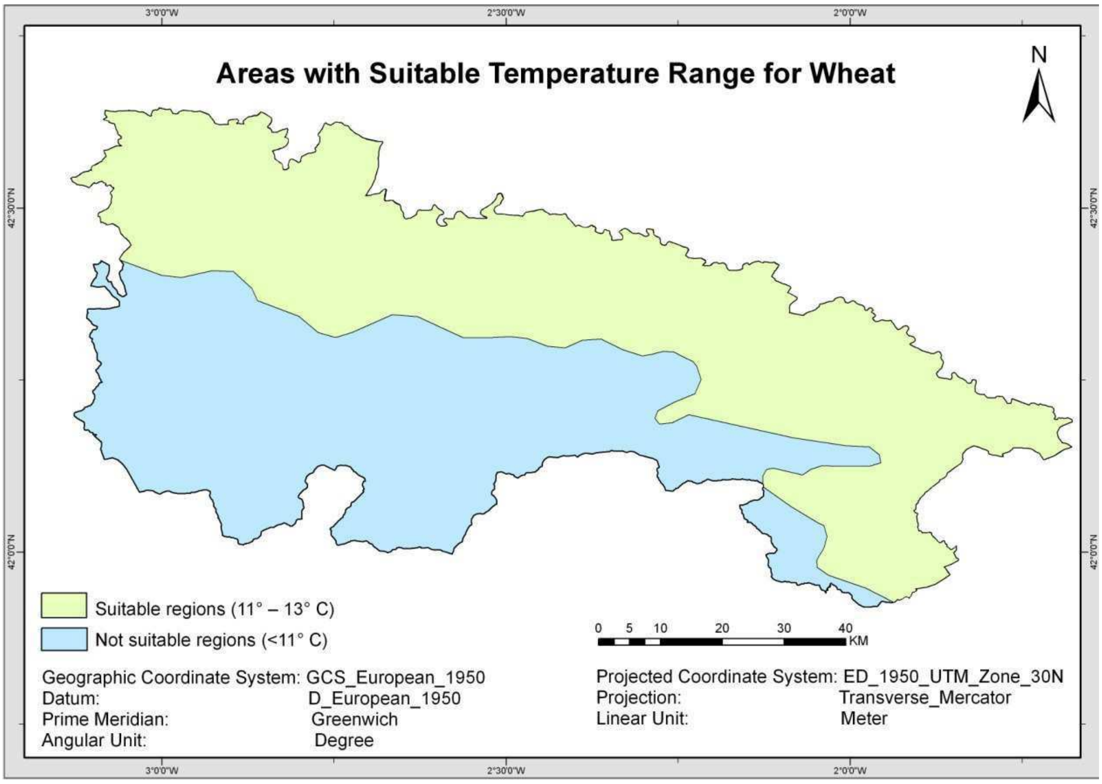

Figure 16. Areas with a suitable temperature range for wheat crop

Figure 16 shows regions with a plausible annual average temperature. At the end, final map has been extracted based on clipping all suitable regions with previous generated maps.

4.3.3 Precipitation

Ghaffari et al. discussed on wheat crop and suggested to plant on regions with annual precipitation of 300 and 500 mm. Therefore, precipitation data set has been clipped based on criteria stated above.

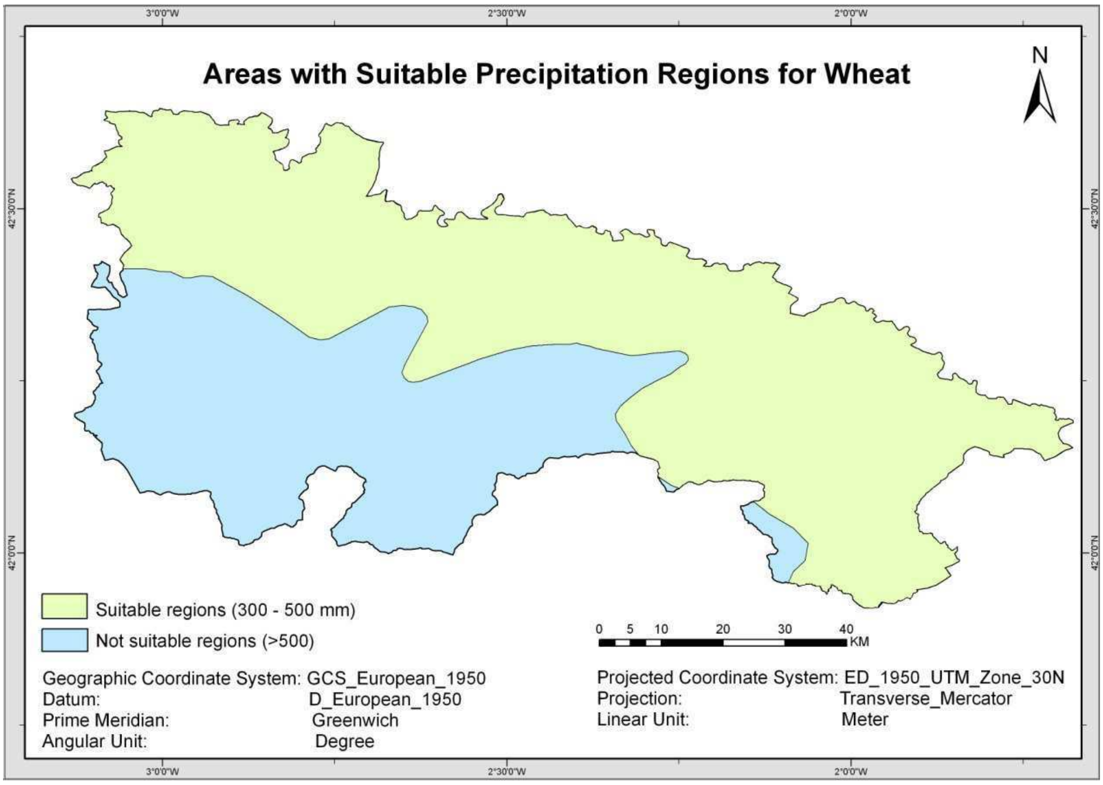

Figure 15. Areas with a suitable precipitation range for wheat crop

Figure 15 presents suitable precipitation areas of wheat crop. Suitable areas are 3128.9 sq km or 62.1% of the total area (appendix 2). The other 37.1% of the study area is unsuitable. The data shows that suitable areas are placed along the course of Ebro River according to the figure. Since, less steepness of southeastern part of La Rioja has resulted in being plausible for planting grape crop. However, some spots can be seen as unsuitable which has been effected by mountains of neighbor province.

4.3.4 Result Map

All plausible regions on particular conditions have been cropped and following figure have been generated to find out suitable areas based on previous outputs,

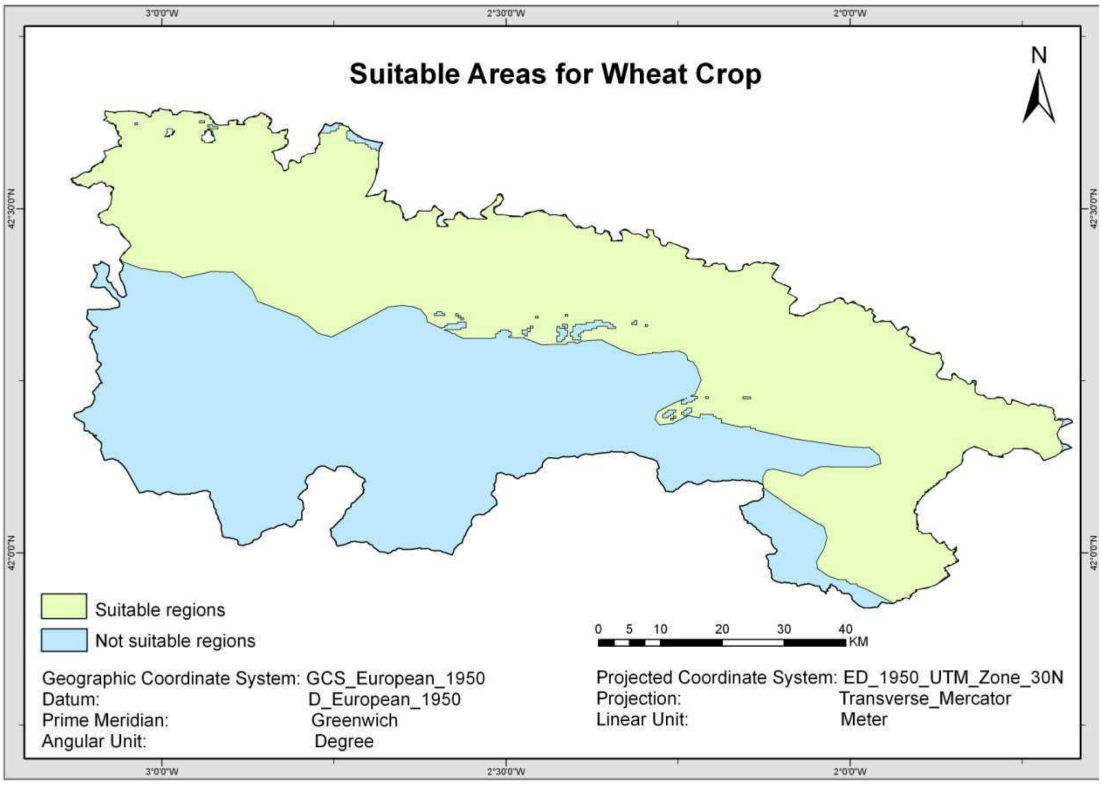

Figure 17. Suitable areas for wheat crop

Figure 17 presents the suitable areas for wheat. The total plausible area is 2672.603 sq km. The region has some unsuitable parts in the central part which has been removed. In general, it can be treated as one large area with minor territory taken out.

4.4 Potato

Potato is fourth-largest food crop cultivated in the world. Asia and Europe produce 80 % of the world's total potato production. Europe's 7.5 million hectare area covered with potato yields. Spain dominates in producing potato among European countries with 28.1 ton/hectare (FAO, 2005).

Penning et al (1995) have discussed different simulation models for research, yield production and decision support. Potato, one of the most planted crop types, has been studied and GIS has been implemented to simulate potato crop growth and its productivity under particular conditions (Haverkort, A.J. and MacKerron, D.K.L, 1995).

Crop systems have been developed not only on the local level, but also regionwide (van Lanen, H.A.J. et al., 1992). La Rioja has very diverse grape crops, however as a main crop *Solanum tuberosum L.* type is used to plant across the region. Further on, potato will be used instead of *Solanium tuberosum L.*

4.4.1 Slope

The study mentioned above suggests slope of 0-10% for plausible area to plant. Therefore, plausible regions with a slope of 0-10% have been extracted.

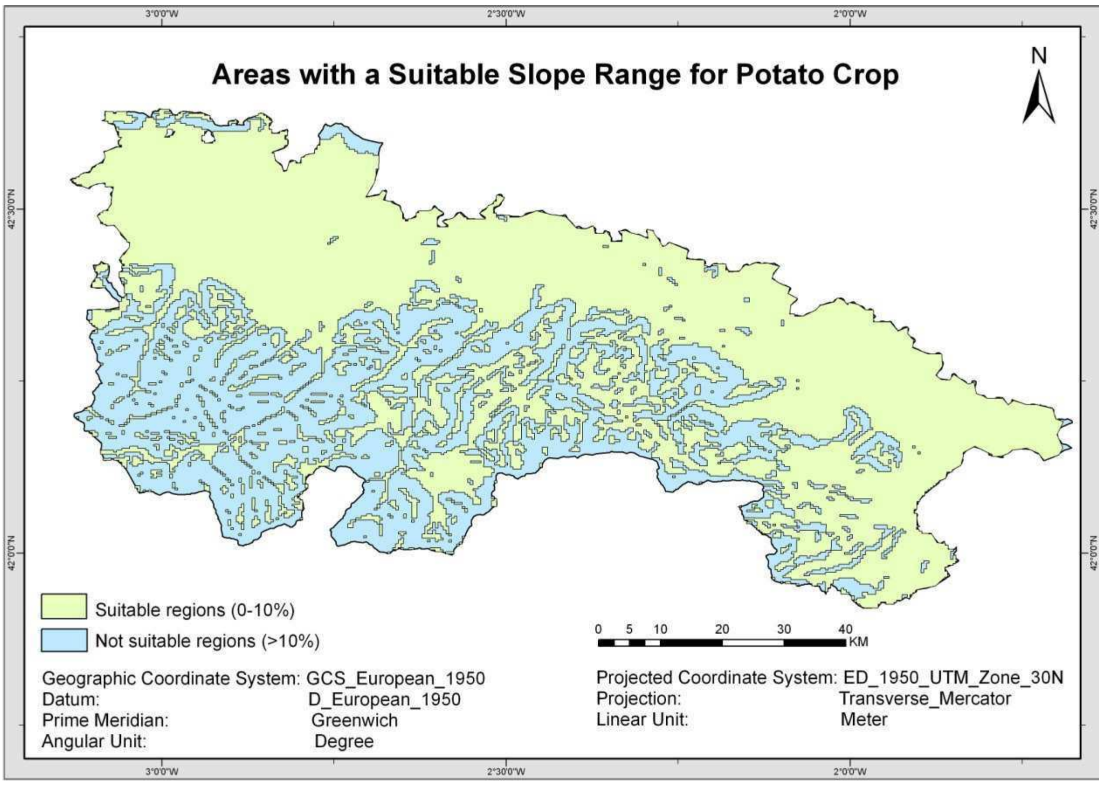

Figure 18. Areas with a suitable slope regions for potato

Figure 18 presents regions with suitable steep areas for potato crops. In total, 3278,34 sq km (65% of the total area) suitable whereas 1763,18 sq km is unsuitable.

Overall, image indicates suitable areas area unevenly distributed in central to western part of La Rioja but evenly distributed along the course of Ebro River.

4.4.2 Temperature

Among geo-environmental conditions the average temperature of the region has a large impact on plausible growth of the crop, since temperature is an inseparable factor to obtain a high harvest. One of the main factors that affect potato growth directly is temperature (Levy and Kedar, 1985; Ewing and Struik, 1992). Streck et al. (2003) have studied how temperature affects potato crop development by simulation and got a highly correlated relationship. Therefore, average temperature of the study area have been examined in order to get suitable regions for potato.

Among the provinces of Spain, La Rioja has the most favorable environmental and ecological condition for potato crop allocation. Garcia-Alvarez et al (2005) has pointed out that La Rioja achieved the highest yields on irrigated and non-irrigated crop lands. As it is mentioned above, La Rioja has optimum yearly average temperature, precipitation, and a valley with low sloppiness and soil characteristics. The analysis results in figure 19 show that large areas of the La Rioja region are suitable for potato planting. The author stated that La Rioja has less than three months in which average temperature is higher than 20^0. This is optimal condition of necessary thermal requirements. Those areas have delivered high income in the last few years. According to Streck et al (2007), the average temperature range should be between 7^0 to 13^0 Celsius. Therefore, plausible areas have been extracted from annual average temperature data.

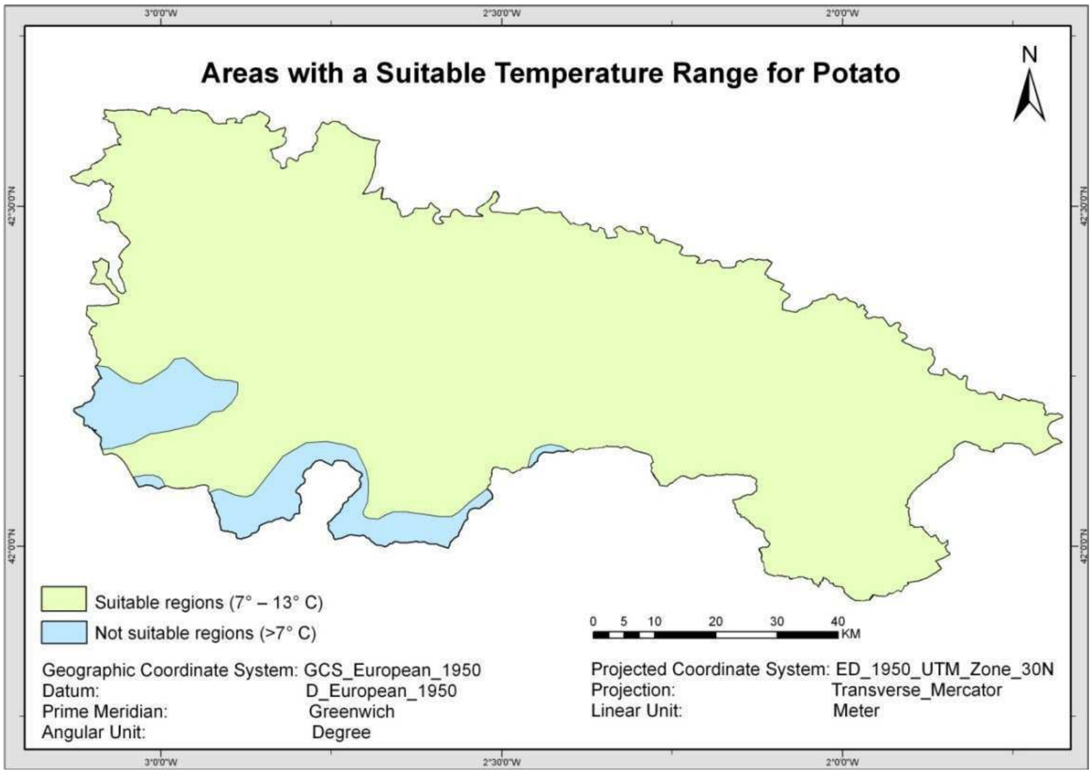

Figure 19. Areas with a suitable temperature range for potato

The figure 19 illustrates regions with suitable temperature range for potato crop. In total, 4673,30 sq km (92,70 % a the total area) has been found plausible for growth of potato crop. Unsuitable areas are placed on south and south western part of of La Rioja.

4.4.3 Precipitation

Streck et al (2007) has argued optimal annual average precipitation range between 300 to 900 mm. Therefore, precipitation data has been cropped to find suitable regions for potato crop.

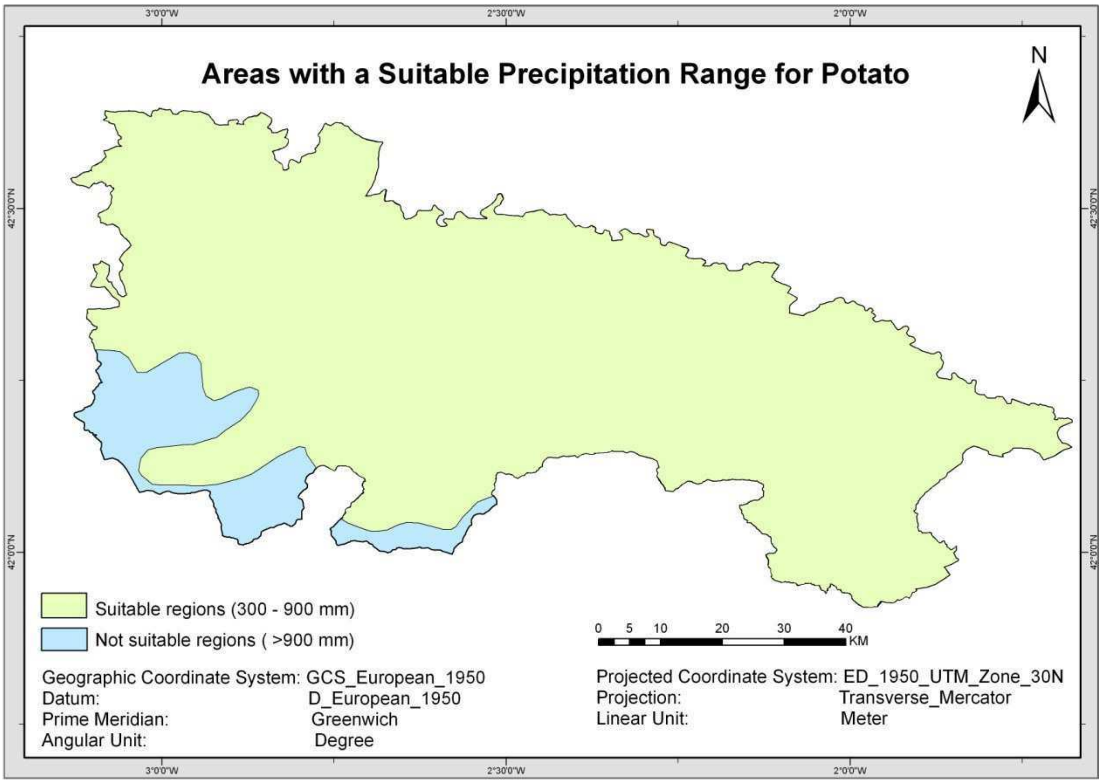

Figure 20. Areas with a suitable precipitation range for potato

Figure 20 illustrates plausible regions for potato crop in terms of annual average precipitation range. Figure draws map suitable areas with suitable to temperature region but slight different in the northwest. In total, 4619,39 sq km is found plausible for the growth of potato in terms of annual average precipitation.

4.4.4 Result map

In order to find suitable areas based on criteria, all plausible regions on required conditions have been clipped and following figure have been generated.

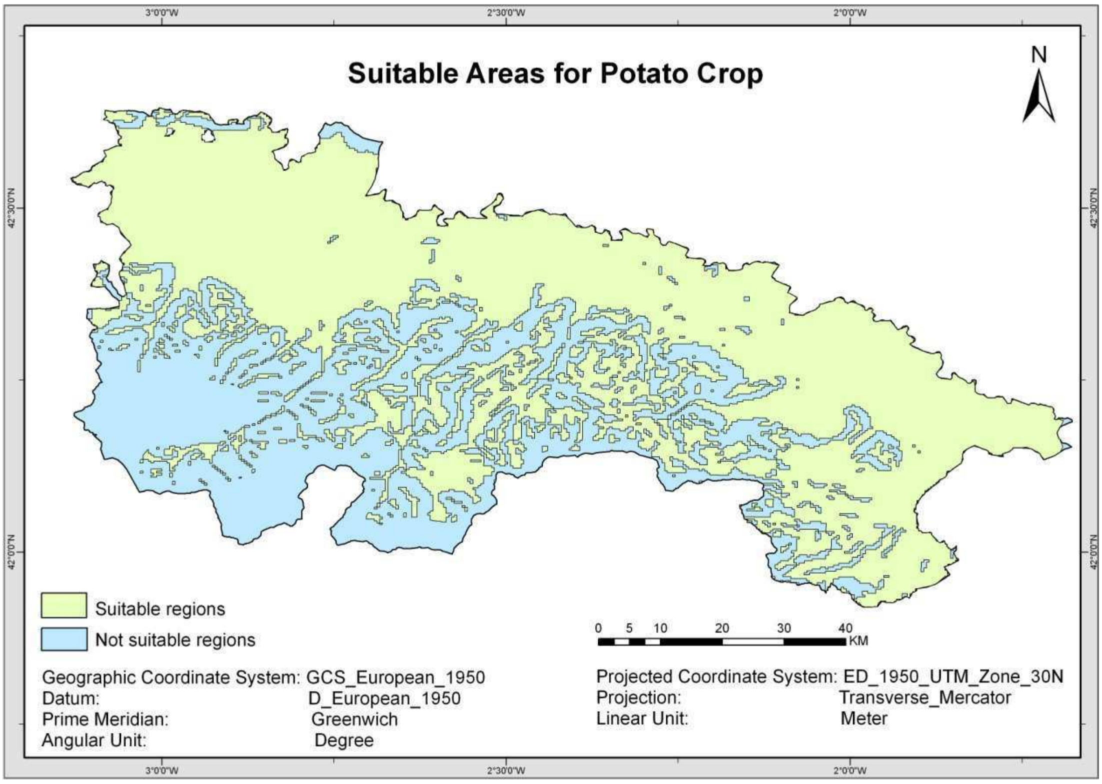

Figure 21. Suitable areas for potato crop

Figure 21 presents suitable regions for potato crop in the La Rioja province. In total, suitable regions are 3192,23 sq km whereas unsuitable areas are 1849,29 sq km. Overall, figure shows plausible areas are for the growth of potato crop are unevenly distributed in central and southern part of La Rioja, but evenly distributed along the course of the Ebro River.

4.5 Barley

According to FAO, Barley is one of the world's most important crops and is ranked as the fourth largest cereal in terms of planted area, with about 566,000 km² with a harvest of 136 million tons. The wild barley *Hordeum spontaneum* is the direct progenitor of the cultivated barley *Hordeum vulgare* (Badr et al. 2000) and both subspecies relatively close as they can be crossed naturally and artificially. Within its distribution range, wild barley has adapted to a large range of eco-geographic variation (Ivandic et al. 2002). Barley is a widely adaptable crop. It is currently popular in Mediterranean areas where optimal conditions are found by nature. In Europe as well as in Spain it is a an important feed grain. Barley naturally prefers cool conditions but it is not winter hardy. Barley from a biological viewpoint is more tolerant to soil salinity than wheat. Since barley grows in a short season and is less tolerant to drought, it gives less flexibility to choose plausible areas according to sites geospatial condition.

4.5.1 Slope

Barley can be grown on slopes up to 20% which is 90% of total area. Therefore, suitable regions has been extracted from slope data and visualized as follow.

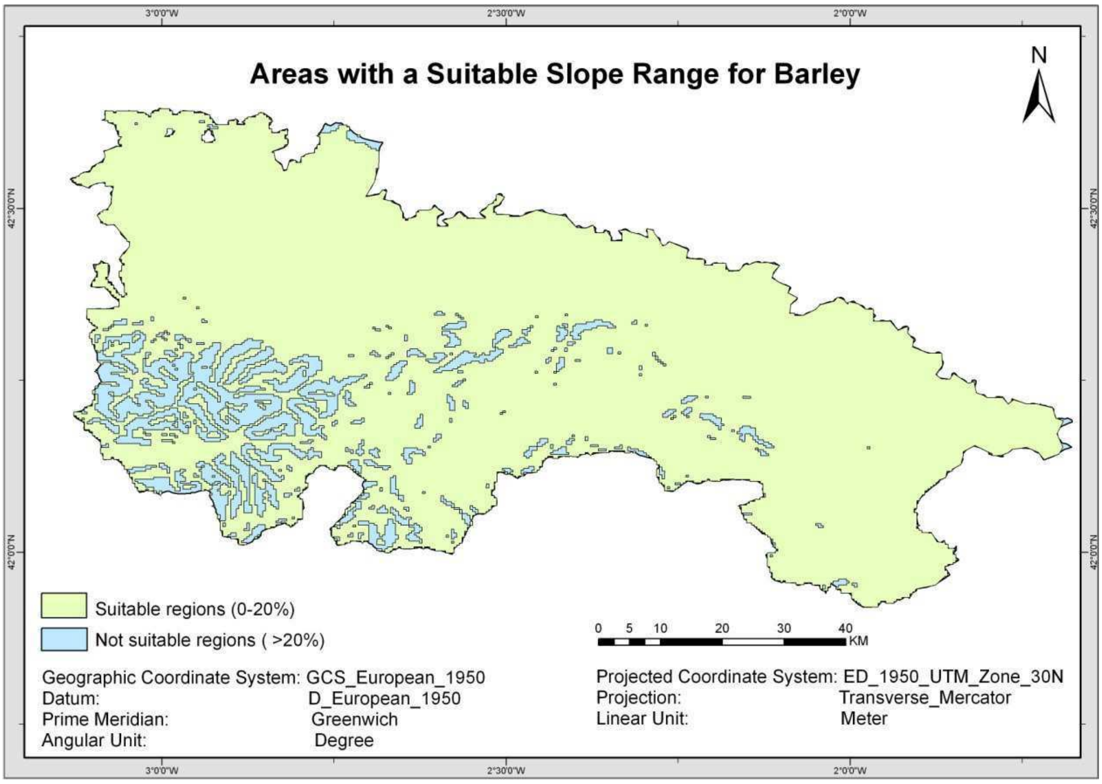

Figure 22. Areas with a suitable slope regions for barley crop

Figure 22 illustrates plausible sloppy regions for barley crop. The figure depicts 90% of total area plausible for planting barley crop. In terms of steep, southwestern part, central and northern part has found unsuitable regions which has slope more than 20%.

4.5.2 Temperature

Schelling et al. (2003) have studied in depth barley crop yields. According to their research, the average temperature of the region should not be lower than 13^0 Celsius. The research shows that barley is less tolerant against temperature. Plausible regions has been extracted from temperature data and visualized as follow.

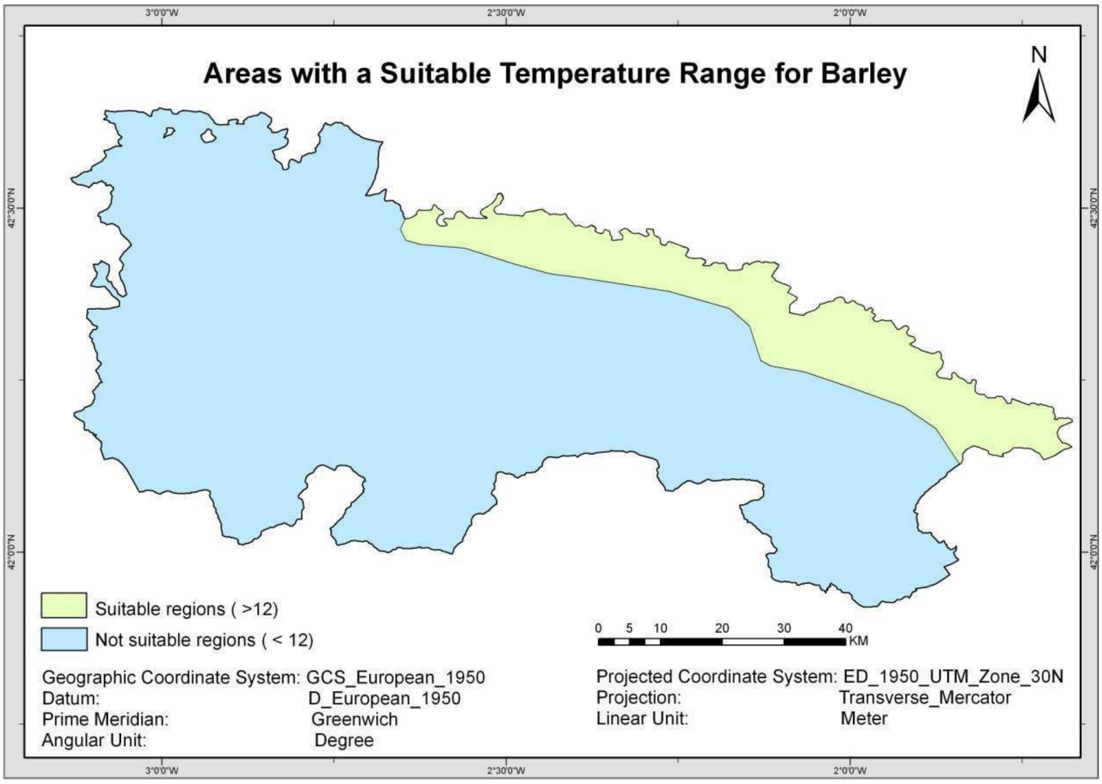

Figure 23. Areas with a suitable temperature range for barley crop

Figure 23 shows, unlike other cereals, is not tolerant to cold weather. Hence, only 726,36 sq km area have been found suitable. Thus, barley can be plant in the northeastern part of La Rioja in terms of annual average temperature range. Suitable areas placed on the course of Ebro River.

4.5.3 Precipitation

Schelling et al. (2003) found that precipitation is tightly correlated with temperature, and suggested precipitation between 400 and 1100 mm. Hence, plausible regions stated above have been cropped from precipitation data.

Figure 24 presents suitable regions with range of 400 to 1100 mm. Figure reveals northeastern part is unsuitable with 547,26 sq km and 4494,26 sq km is plausible for the growth of barley crop. Output from precipitation data shows reverse area is found suitable area which has been found as unsuitable in annual average temperature for barley crop.

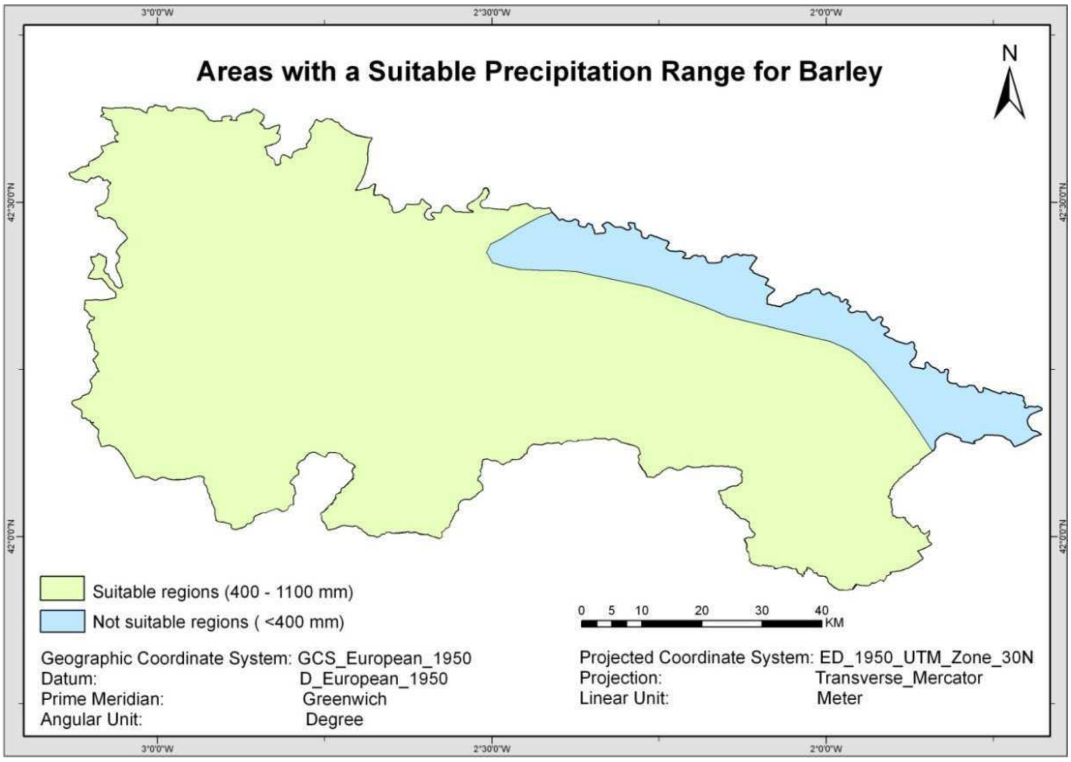

Figure 24. Areas with a suitable precipitation range for barley.

4.5.4 Result Map

Final map has been extracted based on clipping all suitable regions with previously generated maps.

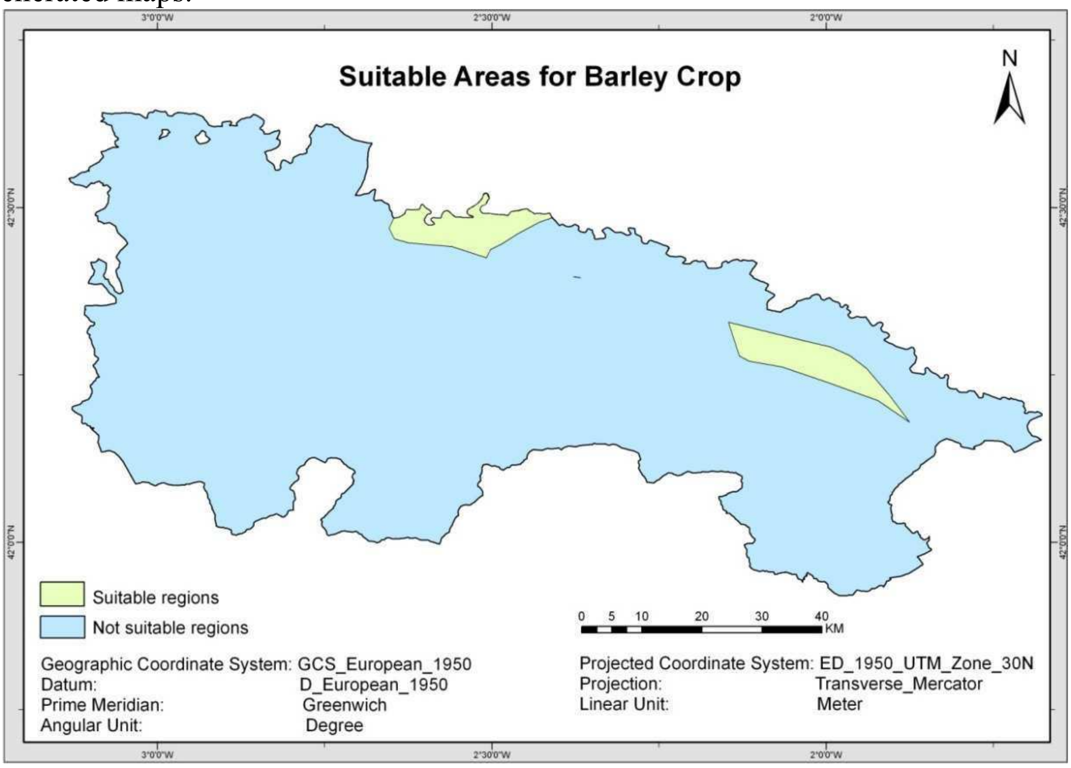

Figure 25. Suitable areas for barley crop.

Figure 25 shows that 195,74 sq km (3,9 % of the total area) is suitable for barley crop. Despite tolerance of barley against steep and high precipitation, result map shows 3,9 % of the total area are found plausible for the growth of barley crop.

4.5 Thyme

Thyme is well-known in medicine and for its culinary use. It is a herb of the *genus thymus*. Thyme is commonly planted in La Rioja. The community offers ideal climatic and geographic parameters for the cultivation of thyme. The nature of the crop requires cultivating it in the spring. It grows under drought conditions, too. Wild thyme plants are found on mountain highlands and this species can tolerate freezes. Hence, the thyme plant is distributed unevenly on the mountains in wild condition, however to manage it properly and get benefit, thyme requires some standard agro-ecological circumstances. These restrictions have been studied by Berkgamp (1998).

4.5.1 Slope

The article says thyme is more adaptable in any hilly areas whose undulation does not exceed 30^0. Thus slope data has been clipped for finding plausible regions.

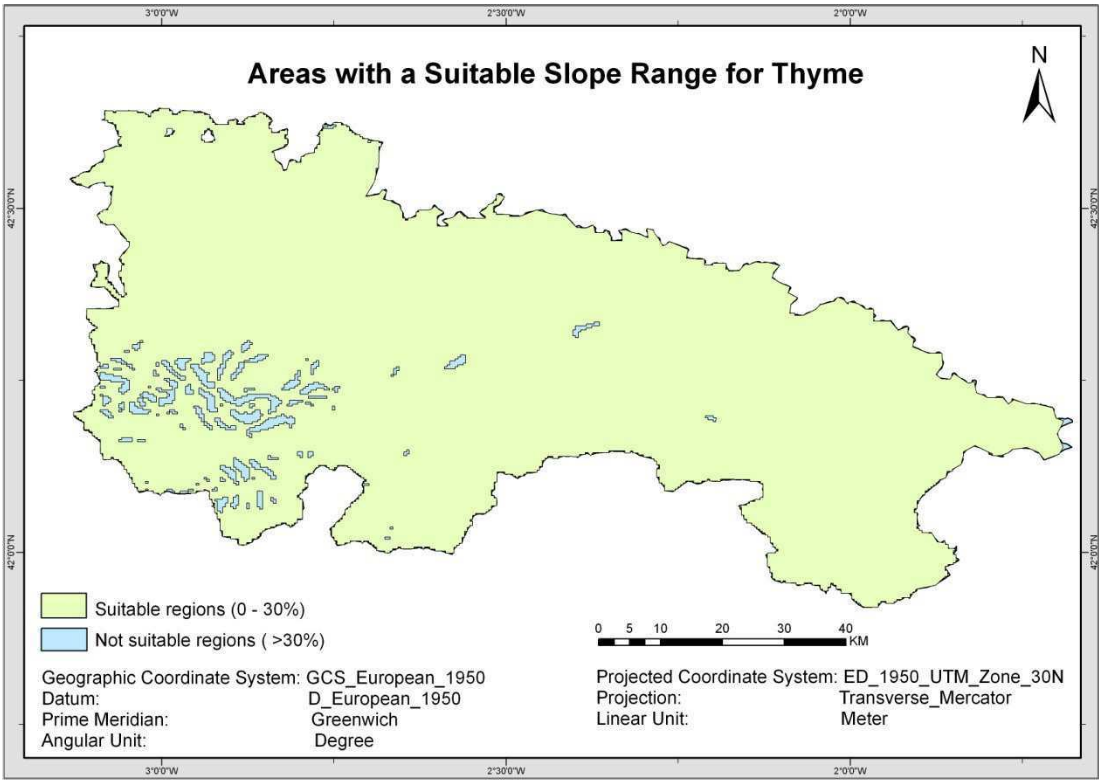

Figure 26. Areas with suitable slope range for thyme

Figure 26 presents extracted suitable sloppy areas for thyme crop. Suitable covers about 98% of total area. Unlike other cereals, thyme is more tolerant against steep results in most of the region is plausible to plant thyme.

4.5.2 Temperature

Berkgamp (1998) has argued and suggested an average annual temperature of 13° C or above for planting thyme.

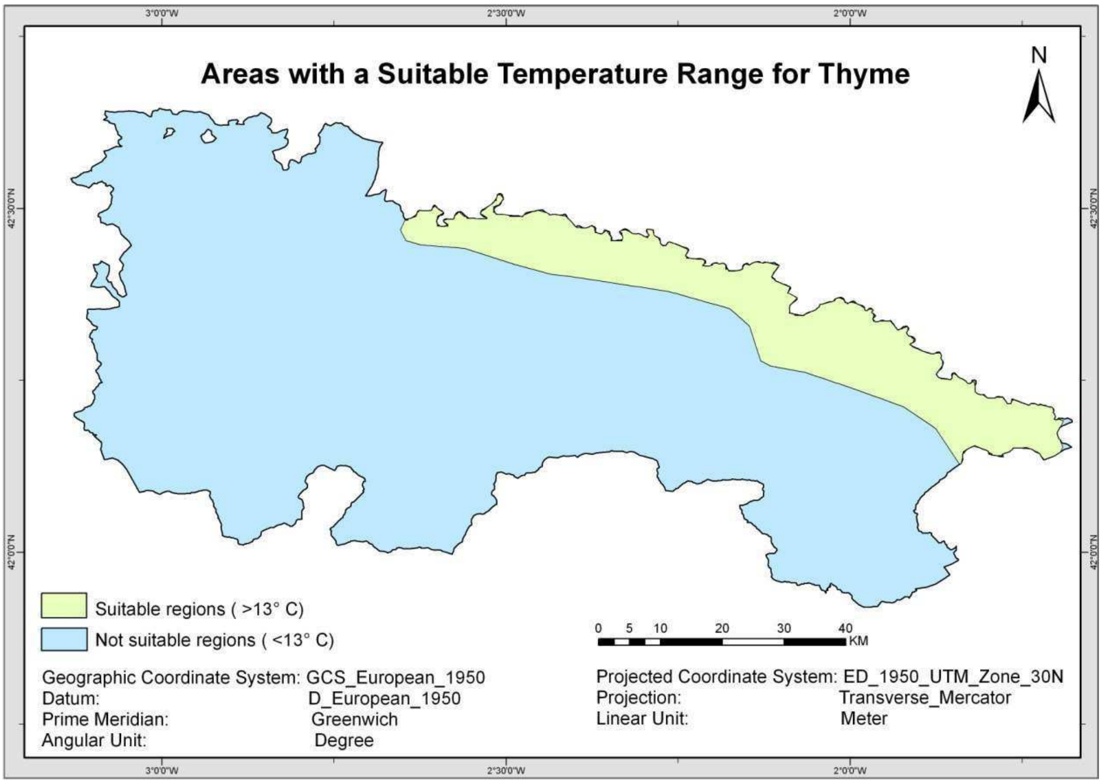

Figure 27. Regions with suitable temperature range for thyme.

Figure 27 shows that plausible region in terms of annual average temperature range placed along the course of Ebro River and it is estimated at 719,03 sq km.

4.5.3 Precipitation

The precipitation needs to be between 200 and 600 mm yearly average (Berkgamp, 1998). For that reason, areas with plausible annual average precipitation have been extracted from precipitation data.

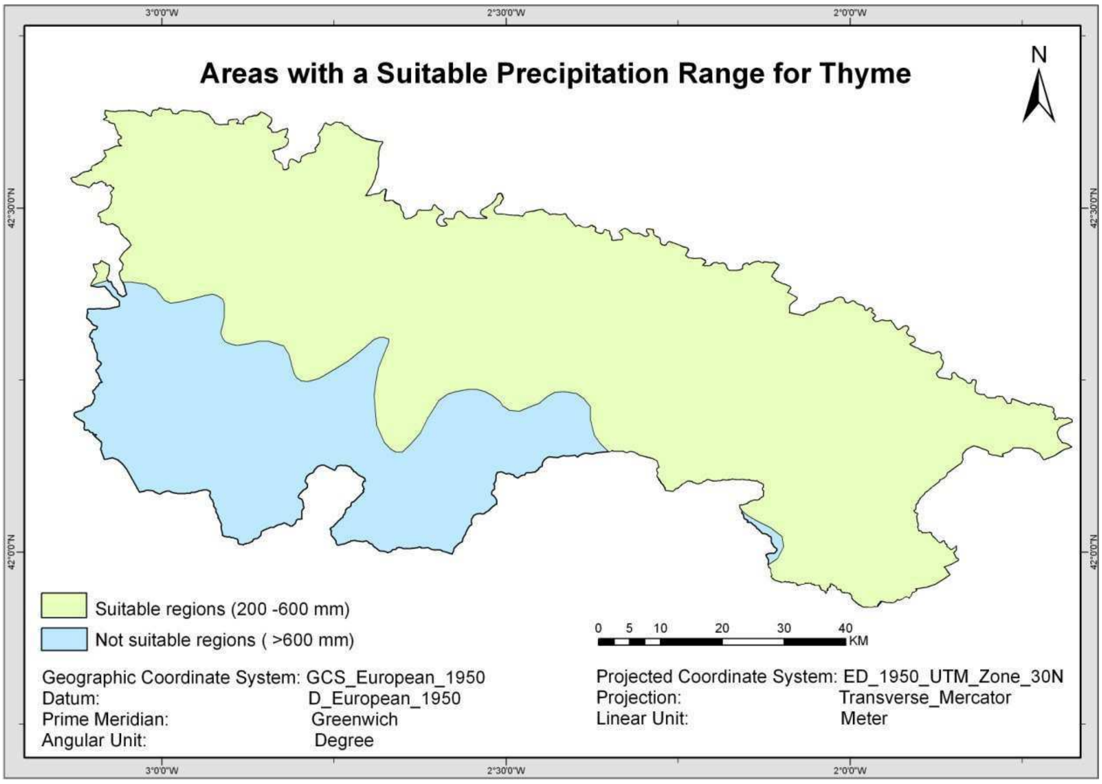

Figure 28. Areas with suitable annual average precipitation range for thyme crop

Figure 28 illustrates plausible area for theme crop in terms of annual average precitation. In total, 3673,38 sq km is found plausible for planting thyme crop. South and southwestern part of the province are found unsuitable.

4.5.4 Final map

Final map has been derived extracting common areas from previously generated maps. First, outcome from temperature data has been clipped by outcome from precipitation data. The result outcome has been clipped by the areas with suitable slope regions. The result has been dissolved to make one area. The result has been displayed as follow (figure 29).

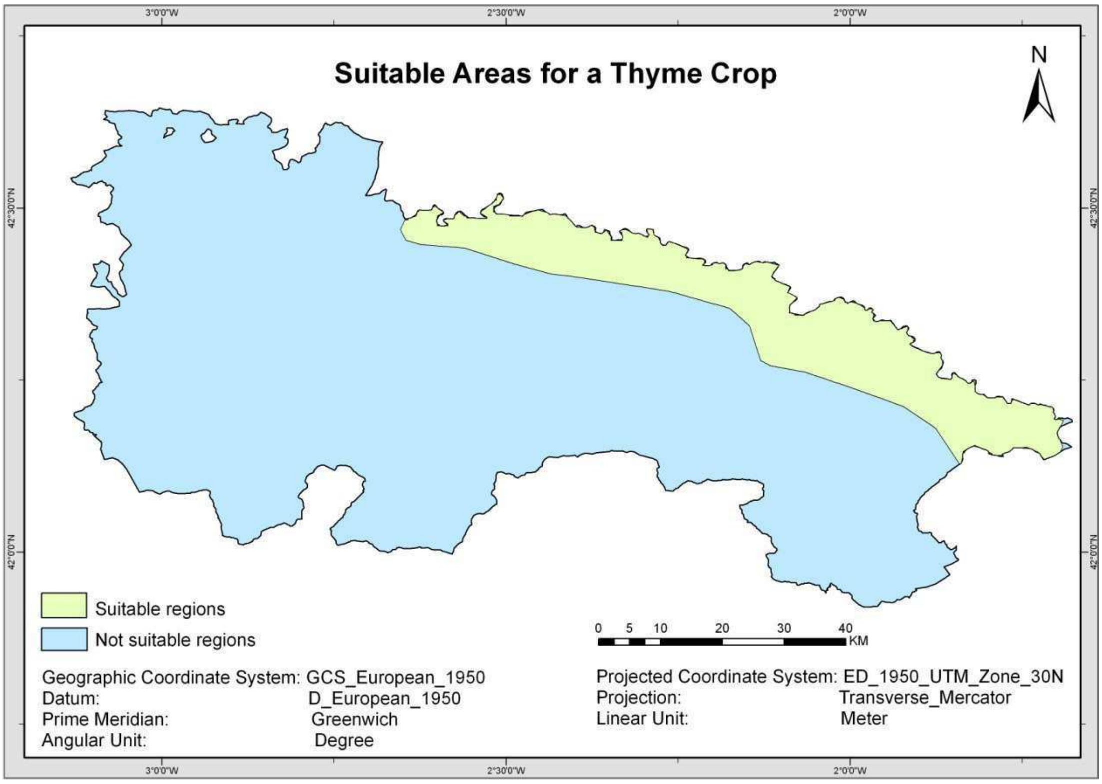

Figure 29. Suitable areas for thyme crop

Figure 29 shows that thyme crop can be planted in 719,03 sq km (14,2% of the total area). The green zone (suitable) is placed in the northeastern part of La Rioja and it is placed along the course of the Ebro River.

In summary, study shows that the northeastern part of La Rioja is plausible for most crops cultivated in the region. Unlike others, barley crop has somewhat different requirements for annual average temperature and precipitation. Thus, outcome for barley crop has given totally different result than other crops.

4.6 Crop Allocation Model

The case studies have been followed sequentially steps one by one. However, these steps can be automated using the model builder in ArcGIS. Figure 22 introduces a crop land allocation model. In order to meet the requirements and reduce time, a crop land allocation model is structured systematically as follows. Spatial data sets have been lined up. The next step projects data sets, selects plausible regions for a crop, and extracts input features that overlay the suitable areas. At the end, suitable areas are dissolved to show one polygon.

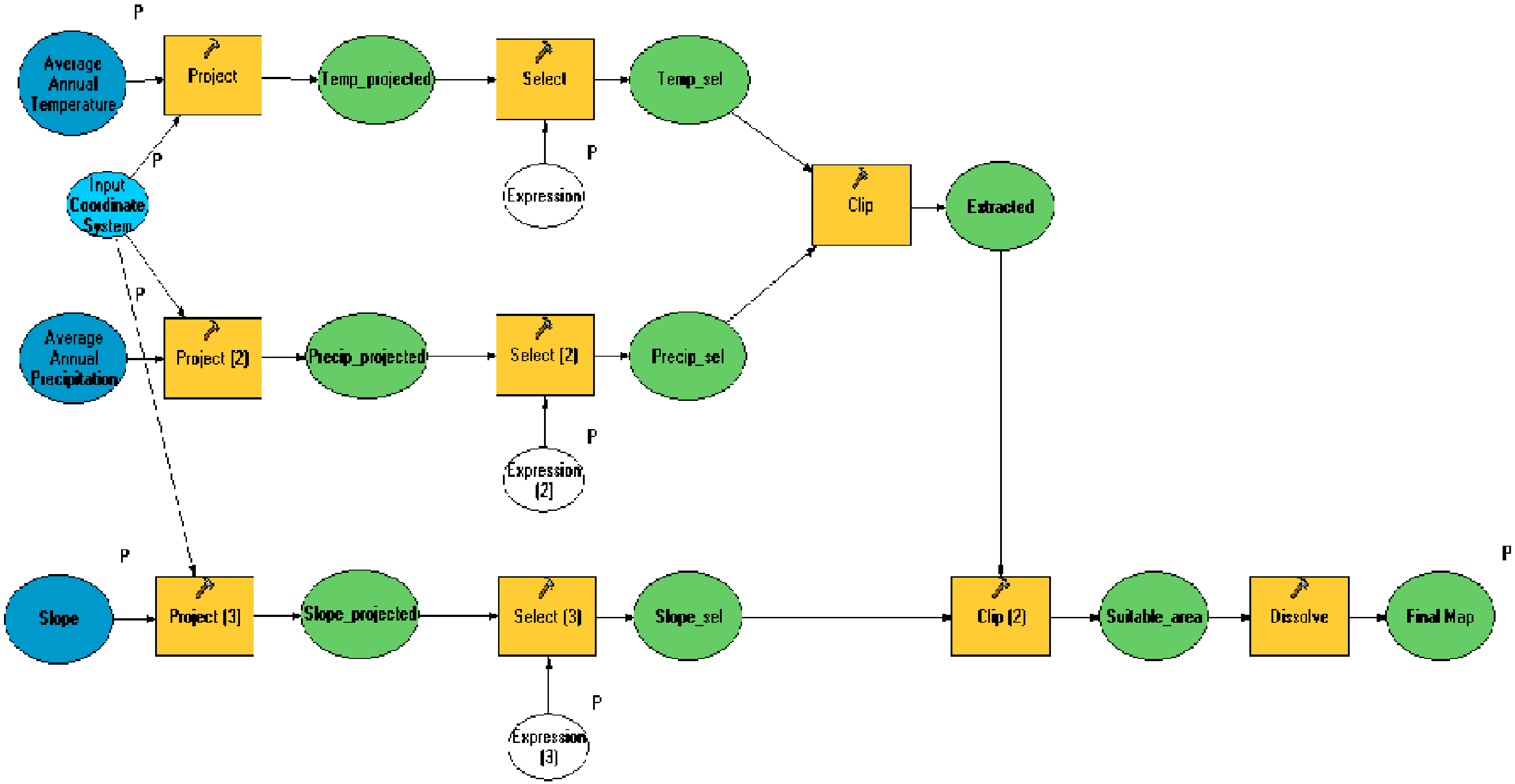

Figure 30. A crop land allocation model

Figure 30 presents a crop land allocation model to find out suitable areas according to the slope, average annual temperature and precipitation spatial data sets. The crop land allocation model has been built using existing functional tools

The crop land allocation model is structured in Model Builder in ArcGIS as follow. The blue circles on the first column are spatial data sets. They are sequentially placed as follow: annual average temperature and precipitation, and slope data. Each blue circle are labeled accordingly. Sign “P” indicates that it is visible to user and it required a particular input from user. The yellow rectangles (labeled “Project”) project three spatial data sets into European Datum 1950, Universal Transverse Mercator Zone 30 North (ED_1950_UTM_Zone_30N). The small blue circle is attached to yellow rectangles on the second column.

The blue circle is set projected system ED_1950_UTM_Zone_30N by default. But it can be changed to different coordinate system in the interface of the model. The green circles on the third column receive the projected data sets. In turn, three data sets pass on yellow rectangle on the fourth column. Yellow rectangles are labeled select which performs extracting suitable areas based on the expression that user inserted. The expression circles are attached to each yellow rectangle. It is white because a criterion for each crop is different and therefore, user needs to insert criteria.

The following green circles receive extracted data with suitable regions. The following yellow rectangles are labeled “Clip”. They perform function to obtain plausible regions based on annual average temperature and precipitation. The result passes the green circle labeled “Extracted”. In turn, the data passes yellow rectangle on the seventh column. The yellow rectangle extracts suitable areas from previously generated data that comes from the green circle on the seventh column based on slope characteristics. Outcome passes the green circle labeled on the eighth column. Final step merges outcome map and create one area, and send the result to the green circle on the tenth column. In turn, the green circle labeled “final map” displays the map on ArcMap.

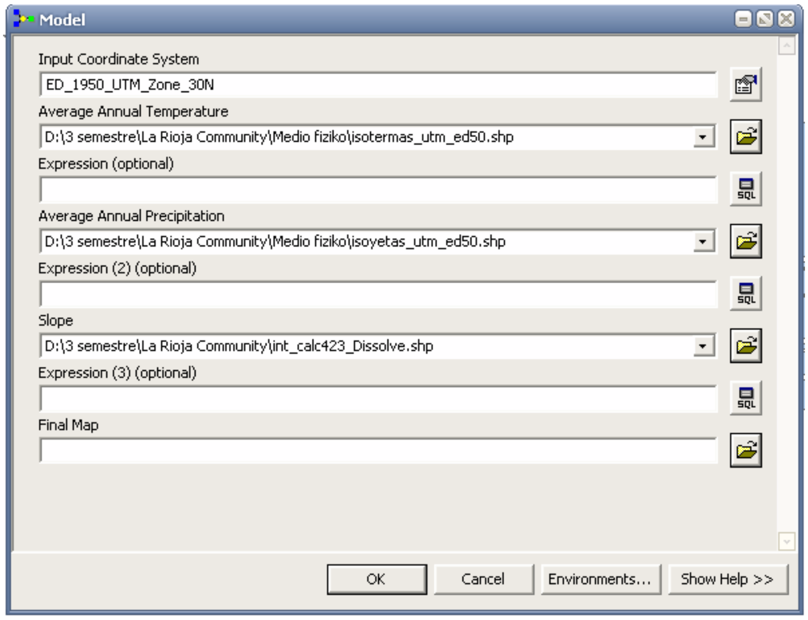

Figure 31. User interface of a crop land allocation model

Figure 31 introduces the user interface of a crop land allocation model. Since the same spatial data sets have been used for all crops, the model asks user to insert only the needed corresponding variables to find out suitable regions to each crops.

The model was applied to each crop with the corresponding variables and the results have given the same result as previously studied. The model proves that for repetitive works such as spatially allocating crops needs to be modeled in order to reduce the time required by the decision-makers and have results immediately.

The current application supports the theoretical framework described in this framework. Moreover, it presents how important it is to consider the effects of the whole policy package and not each measure independently. This is because the latter may induce changes in agriculture land allocation.

CHAPTER 5

CONCLUSION

The following conclusion has been drawn from this research:

- More spatial data sets increase the reliability of the result;
- More accurate data will lead to a more accurate result;
- A standardized requirements framework for a particular crop should be applied to regions with similar characteristics;

The research has limited accuracy due to the coarseness of the data sets but opens important opportunities for further, more accurate results that can be achieved with disaggregated data sets.

The result has been generated based on the available spatial data sets. However, the accuracy of the result does not depend on the techniques that were used. Taking into account different parameters, suitable areas for wheat and grape crops will be an important starting point for decision-makers in La Rioja. This application proves that GIS is invaluable tool in the development of rural planning and the same technique could be applied for regions with similar geospatial attributes.

Suitable areas represent roughly the productivity of a region but sustainable yields change from year to year. In general, based on spatial data sets, a particular crop type can be allocated. There is a tremendous amount of factors that directly or indirectly affect crop allocation within the region. Unexpected conditions such as flooding and rising underground water levels are also a natural influence that may bring unexpected results. Unsuitable areas are those that are found to not match geospatially, based on the standardized framework. Although, geospatial allocation limitations can be applied in any region for successful sustainable use of land for the crop. The criteria used for classifying land as 'unsuitable' in this study area were based on slope, average temperature and precipitation rather than on all climatic characteristics.

The crop land Allocation model has given the same result with studying manually. It proves that the crop land allocation model is valuable help to decision-makers in reducing time. For further development of crop land allocation, we suggest the use of spatial data with a higher resolution and more geophysical and geo-biological parameters for the study area. This will ensure more reliability and accuracy of the results.

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Annex

Annex 1

FID	Shape	Slope angle	Area, km^2	FID	Shape	Slope angle	Area, km^2
0	Polygon	0	731,6602	26	Polygon	26	31,75757
1	Polygon	1	486,0717	27	Polygon	27	33,16011
2	Polygon	2	394,0988	28	Polygon	28	26,27377
3	Polygon	3	306,7904	29	Polygon	29	23,82019
4	Polygon	4	252,4516	30	Polygon	30	19,01526
5	Polygon	5	214,6027	31	Polygon	31	17,584
6	Polygon	6	199,3662	32	Polygon	32	14,17356
7	Polygon	7	189,247	33	Polygon	33	15,74382
8	Polygon	8	175,7088	34	Polygon	34	10,52995
9	Polygon	9	168,655	35	Polygon	35	10,22326
10	Polygon	10	159,6873	36	Polygon	36	8,792001
11	Polygon	11	170,0047	37	Polygon	37	5,725024
12	Polygon	12	181,0901	38	Polygon	38	4,702698
13	Polygon	13	163,0727	39	Polygon	39	4,498233
14	Polygon	14	151,0761	40	Polygon	40	3,782605
15	Polygon	15	140,0586	41	Polygon	41	3,271442
16	Polygon	16	116,3774	42	Polygon	42	2,862512
17	Polygon	17	106,833	43	Polygon	43	2,249116
18	Polygon	18	88,6724	44	Polygon	44	1,533489
19	Polygon	19	82,76356	45	Polygon	45	2,658047
20	Polygon	20	70,07883	46	Polygon	46	1,022326
21	Polygon	21	62,56633	47	Polygon	47	0,920093
22	Polygon	22	56,75665	48	Polygon	48	0,511163
23	Polygon	23	46,72028	49	Polygon	49	0,306698
24	Polygon	24	41,09749	50	Polygon	51	0,204465
25	Polygon	25	37,31489				

Annex 2

FID	Shape	Pecipitation	Area
1	Polygon	500	86,1396
2	Polygon	500	15,7017
3	Polygon	400	1472,44
4	Polygon	500	1003,22
5	Polygon	300	551,375
total			3128,876