Forecasting of Winter Wheat Yield for Turkey Using Water Balance Model

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Abstract— Climate is one of the most important factors affecting agricultural production which is under the influence of climatic factors such as rainfall, rainfall distribution and temperature during the year. Many methods have been developed for crop monitoring and yield forecast using climatic data for recent decades. Statistical approach, crop simulation and remote sensing methods have been widely used for the yield forecasting studies. In this study, AGROMETSHELL software developed by FAO for arid regions was used. AGROMETSHELL model produces water balance parameters (WRSI) which is calculated from total evaporation values that take for actual rainfall and crop coefficients between planting and harvesting dates. In this project Water Satisfaction Index parameters, calculated by Agrometshell model, were regressed with historic crop yield statistics of State Institute of Statistics to produce crop yield forecasts before harvest time. Yield forecasts were produced at provincial level and expected increases and decreases in yield are calculated as percentages (%).

Keywords— Wheat, Yield Forecasting, Water Balance

I. Introduction

Agricultural policies plays an important role in effectively use of the country's natural resources. For agricultural crops, it is necessary to know cultivation area, the amount of yield and production before harvest is important for agricultural planning. Crop forecasting usually provides information about crop yield and production quantities a couple of months in advance of the harvest.

Climatic factors affect agricultural production significantly despite the development of agricultural techniques. Temporal and spatial changes of meteorological factors cause big fluctuations in agricultural production. For this reason agrometeorological simulation methods have been developed that make use of such meteorological parameters for crop monitoring and crop yield forecasting. Agrometeorological crop yield forecasting methods provide a quantitative estimate of the expected crop yield over a given area, in advance of the harvest and in a way that constitutes an improvement over trends, provided no extreme conditions occur. They are based on the common-sense assumption that weather conditions are the main factor behind the inter-annual (short-term) variations of de-trended crop yield series.

Water is one of the most important limiting factors of agronomic crop production throughout the world. Taking into consideration water supply conditions is essential in the yield estimations, in the yield forecasts or in the plant-weather modelling as well. Most cereal production in the Anatolian Plateau is rainfed and, therefore, exposed to the inter-annual variability of rainfall which directly affects the variability of the main cereals production. FAO has developed Crop Water Balance Models of yield prediction due to the lack of low-cost methods that are available for developing countries [1]. FAO water balance approach developed by Frère, and Popov [2]. This approach is based on agro-meteorolojik station data to estimate of the plant conditions and yield [3], [4]. Water balance model(WBM) is simple, but it is a physical approach to monitor the growth during plants growth period. Water balance models are based on agro-meteolorojik data and required a large number of data. On the other hand, when compared with other plant growth simulation models or statistical regression WBM has been proven to be easily implemented and provide accurate results [5].

In this study simulation method developed by FAO has been implemented for cereal yield forecasting of Turkey.

II. Materials and Method

A. Climatic data

Meteorological data is taken from the State Meteorology Affairs General Directorate. There are 265 meteorolojical station nationwide. These historical, actual and daily data are maximum temperature, minimum temperature, mean temperature, relative humidity, precipitation, wind speed, global radiation and sunshine hours.

B. Collection of Agricultural Statistics

State Institute of Statistics has the responsibility to produce and disseminate official statistics for Turkey including annual agricultural production statistics. The agricultural statistics are compiled from data collected from the local estimates (800 districts) by technical staff of Ministry of Food, Agriculture and Livestock (MFAL). The Department of Research and Statistics of MFAL collects questionnaires filled in by technicians at the district and provincial levels. These area and yield statistics are being collected not in a systematic way but in a subjective approach.

C. *AgroMetShell*

The AgroMetSell is developed by FAO Environment and Natural Resources Service (SDRN) that provides a toolbox for agrometeorological crop monitoring and forecasting. It is a user friendly tool with a “visual menu” that offers easy access to some of the most often used functions. The programme includes a database that holds all the weather, climate and crop data needed to analyse the impact of weather on crops. Crop Specific Soil Water Balance model produces a number of outputs for the various stages in the growth and development of the crop. In developing models for yield estimation, the various outputs are regressed with historical yield data [6].

D. *FAO- Water Balance*

Based on the meteorological and agronomic data, several indices are derived which are deemed to be relevant variables in determining crop yield, for instance actual evapotranspiration, crop water satisfaction, surplus and excess moisture, average soil moisture, etc. The model run by decad time period by using actual meteorological data. The indices (variables) calculated by model then regressed with historical crop yields to develop an equation (the yield function) to estimate station yield.

Water balance model determines the amount of water on increased water stress by recording a cumulative time period for certain plants for all growing season. Water balance or water budget is calculated in the decad time periods. One month period is usually too long for agricultural analysis because four weeks may hide significant agro-meteorological events such as dry spells one or two weeks long. On the other hand using one-day periods can lead too excessive data processing when dealing with a large number of stations.

In FAO water balance model monitored main parameters is soil moisture, not the rainfall itself because plant takes soil water from the root zone. Estimating soil humidity provides the accuracy of prediction of water balance [4], [7].

FAO water balance approach have two main outputs which have positive relationship with crop yield; Actual evapotransprarion (ETa) and Water Requirement Satisfaction Index (WRSI).

E. *Water Requirement Satisfaction Index (WRSI)*

Water requirement satisfaction index (WRSI) is an indicator of crop performance based on the availability of water to the crop during a growing season. Doorenbos and Pruitt, [8] have shown that WRSI can be related to crop production using a linear yield-reduction function specific to a crop in FAO studies. The WRSI index gives a qualitative assessment of crop condition, but combining the water balance model with crop yield functions can give quantitative yields [4].

WRSI; is calculated by AgroMetSell software developed by FAO, taking into account water requirement during the plant's growth period.

WRSI for a season is based on the water supply and demand a crop experiences during a growing season. It is calculated as the ratio of seasonal actual evapotranspiration (AET) to the seasonal crop water requirement (WR):

$$WRSI = (AET / WR) * 100. \quad (1)$$

WR is calculated from the Penman-Monteith potential evapotranspiration (PET) using the crop coefficient (Kc) to adjust for the growth stage of the crop. Developing a set of crop coefficient curves for estimating the seasonal water requirements is accomplished by knowing the precise length of the growing season for a given location and estimating the relative length of each crop stage.

$$WR = PET * Kc \quad (2)$$

Calculating PET requires agro-meteorological measurements of temperature, wind speed, relative humidity,and sunshine. In this study PET was calculated by Penman method in AgroMetSell sofware.

When the WRSI is equal to 100, it indicates no water stress and good crop yields, while a WRSI of 50 corresponds to poor crop yields or crop failure.

III. RESULTS AND DISCUSSION

WRSI is calculated for each weather station separately, it ranges from 0 to 100. Each station WRSI value was interpolated using by IDW (Inverse Distance Weighting) method to obtain the WRSI for the places which has no station. As a result of this process raster WRSI layers was produced for each year. Using all this layers WRSI anomaly map of Turkey was calculated. The WRSI anomaly map shows the relative magnitude of the WRSI as a percentage of the median WRSI:

$$WRSI\ Anomaly\ (\%) = (Current\ WRSI/Average\ WRSI) \times 100 \quad (3)$$

where "Current WRSI" is actually the current WRSI that is the end of season, and Average WRSI" is WRSI generated using the average of WRSI layers data from 1982 -2014.

Comparision of this year WRSI and average WRSI was given in Figure 1 as percentage. Right from dark red to dark blue WRSI value increases. In dark blue area WRSI values are bigger than normal. Because of very rainy season (2015) generally WRSI is higher than normal country-wide.

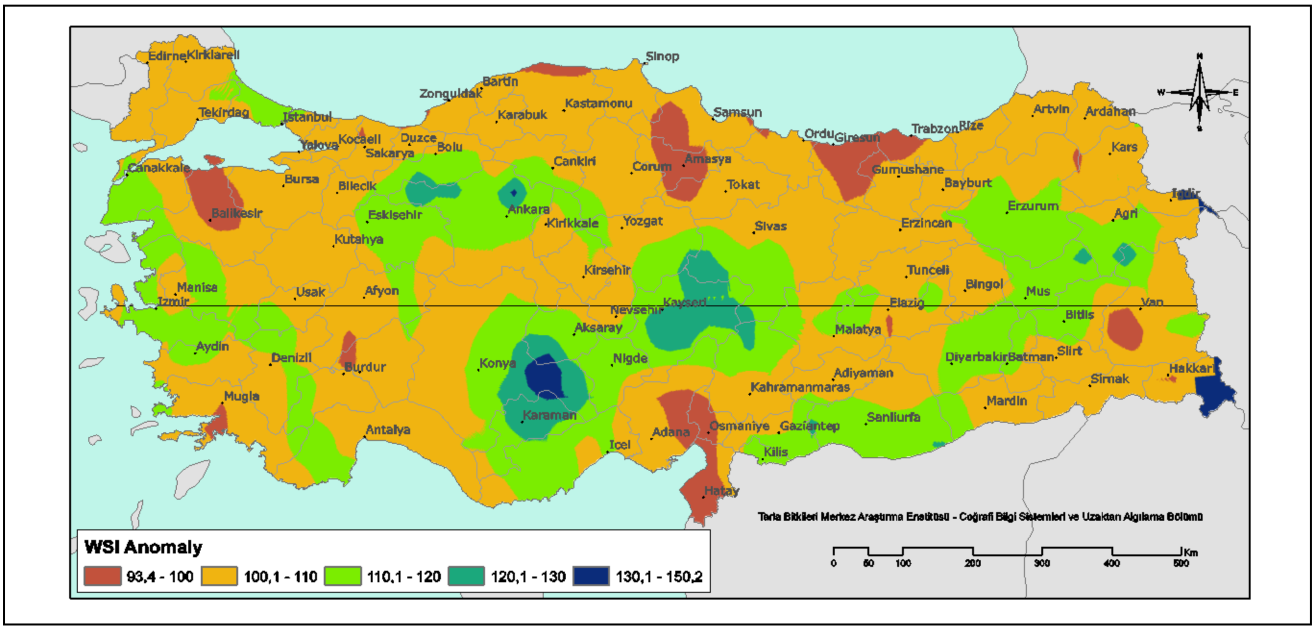

Figure 1. Water Requirement Satisfaction Index anomaly map

The AgroMetSell software produces water balance parameters (WRSI) which is calculated from total evaporation values that use actual rainfall and crop coefficients between planting and harvesting dates. In this project Water Satisfaction Index parameters, calculated by AgroMetSell model, were regressed with historic crop yield statistics of State Institute of Statistics to produce crop yield forecasts before harvest time.

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Yield forecasts were produced at provincial level and expected increases and decreases in yield are calculated as percentages (%).

Comparision of this year forecasted yield and average yield was given in Figure 2 as percentage. Because there is enough precipitation, winter wheat yield is expected to increase this year compared to average yield. Right from yellow to dark blue forecasted yield increases.

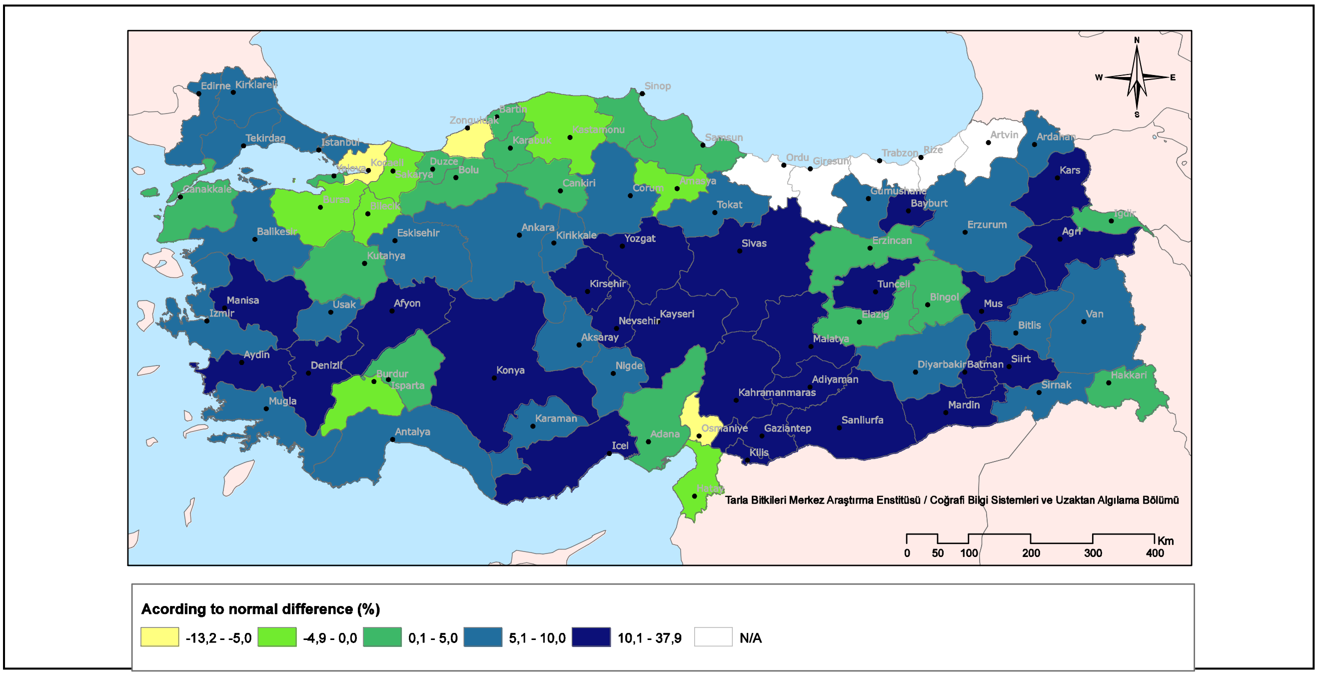

Figure 2. 2015 forecasted yield and average yield

The R2 correlation values between estimated yield and statistics data were 0.84, 0.77, 0.70, 0.74, 0.84, 0.87, 0.64, 0.80, for Turkey overall, Central Anatolia region, Marmara Region, Aegean Region, Eastern Anatolia Region, Mediterranean Region, Southeastern Anatolia Region and Black Sea Region respectively (Figure 3).

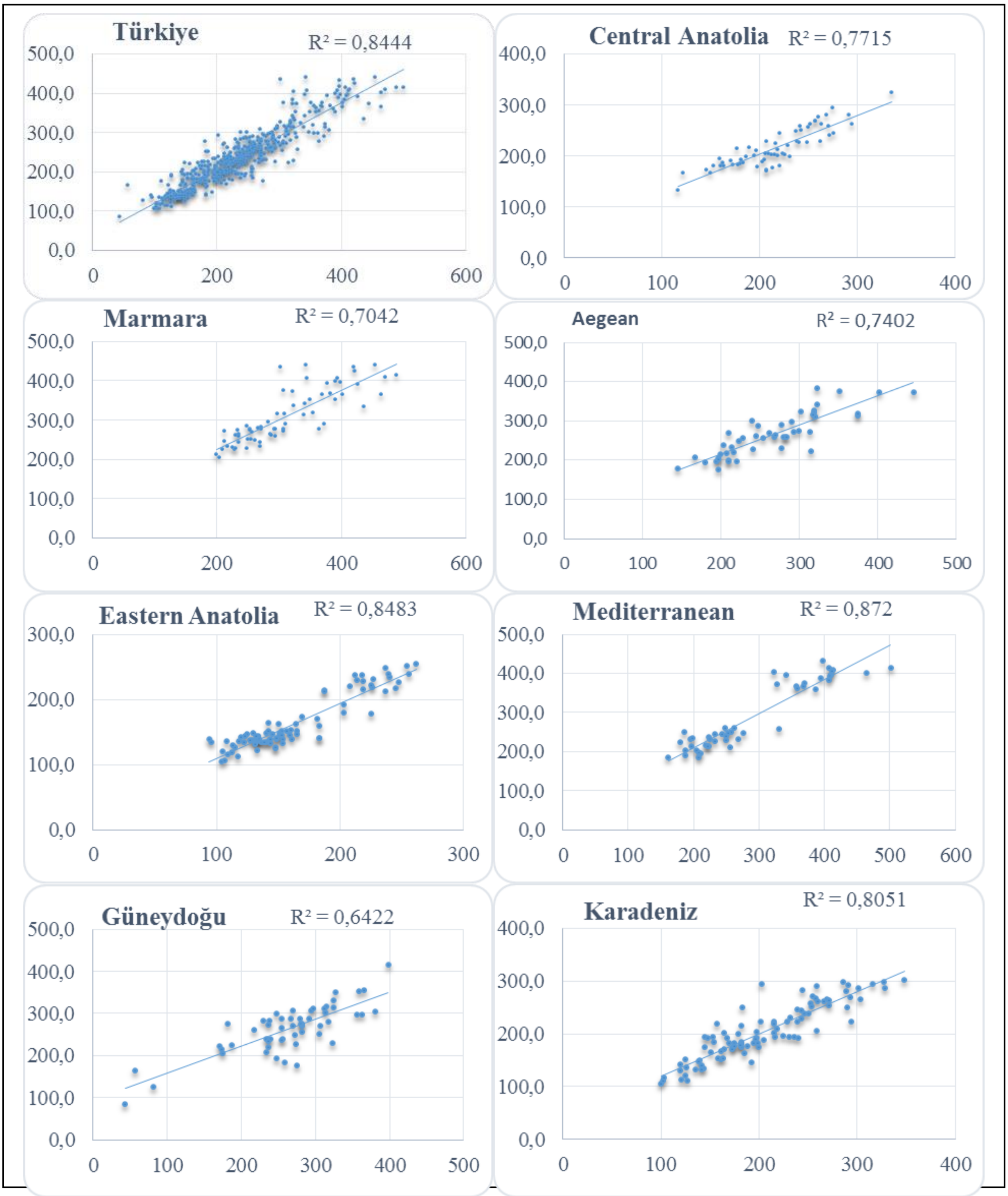

Figure 3 Corelation between forecasted yield and actual yeild (TÜİK statistics)

IV. CONCLUSIONS :

Different yield forecasting approaches have been used by countries according to their needs and capabilities. Such as through questionnaries by farmers, statistical methods, remote sensing techniques, agrometetorological methods or combinations of two or more methods. Crop Water Balance model developed by FAO is used in this study. The method is relatively easy to implement and it is suitable for countrywide crop monitoring and forecasting studies. The model especially suitable for rainfed farming conditions and gives satisfying results for regions as Central Anatolia. Agricultural production is complex and dynamic and being affected by many factors.

Especially Turkey has diverse agro-ecological regions because of topography. Different crop forecasting methods should be develeoped to adapt these different conditions.

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