MANAGEMENT DECISIONS ON FARM-LEVEL AND THEIR LINK TO WEATHER REQUIREMENTS: A CASE STUDY FOR THE UPPER DANUBE RIVER BASIN

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Abstract — **It is undeniable that the global warming has already affected the Earth's biota, whereby the rise of air temperature is an important factor. Agricultural systems are also affected by climate change via the interrelated bio-physical layers. Climate influences farmers` decisions in crop management. To simulate the interactions between climate/weather and the different crop management activities an agent based modelling approach is used, in which farmers` decision making is based on crop requirements from literature. To validate these decision algorithms on how farmers arrange their daily crop management decisions like planting, fertilizing, and harvesting due to changes of climate parameters, a statistical analysis of empirical data (1970-2003) on temperature and different crop growth stages, which represent different management activities, was carried out. Results show that every crop has to be considered separately and the requirements of the different crops on temperature have to be observed in different ways. There are crops which have a low germination temperature, for those the average daily temperature shows no relation with the planting day. In this case the temperature sum in a specific period is more precise. On the opposite side crops with a high germination temperature show significant correlation results with the average daily temperature of a period before the planting day.**

Keywords — **Crop management, heuristic decisions, regional climate change**

I. INTRODUCTION

In crop production the choice of location for a specific crop is influenced by the three main factors climate, soil and the requirements of the crop. The yield is determined by these three factors. Another important aspect of productivity is the crop rotation and the cultivation way of the farm manager. The often discussed climate change leads to a change of these local and natural factors. The natural environment indicates this by the earlier appearance of phenological stages [1]. Although the climatic conditions of a location are slowly changing, the natural environment is a main factor in rating the economical efficiency of a location [2]. To understand this slowly changing interaction between climate/weather and the crop production decisions of a farmer, which are often based on economical aspects, an agent based model was build up. This model was calibrated on the catchment's area of the river Danube. The model simulates the daily decisions of a farmer under different climatic conditions. The main purpose lies on the survey of changing planting, fertilizing, and harvesting dates and the resulting changes on yield. These decisions are influenced by the knowledge of farmers on the past years and the actual weather. The decision algorithm is based on the different requirements of the different crops and stages, whereby the main purpose lies on the decision of planting the crop. With the date of planting the growing period of the plant is integrated in the local weather course. The necessary information about development stages and yield will be provided by a crop growth model. To emphasize the parameters of the decision algorithm a statistical analysis on empirical data concerning the date of planting and the temperature was carried out.

II. METHOD

The project area is the Upper Danube catchment which covers an area of 77,000 km² and it includes glaciers as well as temperate lowlands, which are intensively used by agriculture.

The agent-based model is based on so-called heuristic agents. These are agents which have relative simple rules that guide them in their decision-making. In general the underlying decision trees on planting, fertilizing, and harvesting were realized by creating deductive decisions out of general knowledge on the climate requirements of different crops mainly based on literature. Figure 1 shows the decision to plant winter wheat, which depends on the crop requirements in specific stages, like e.g. the need of enough rainfall during heading and the actual weather condition at the certain day the agent planned to plant.

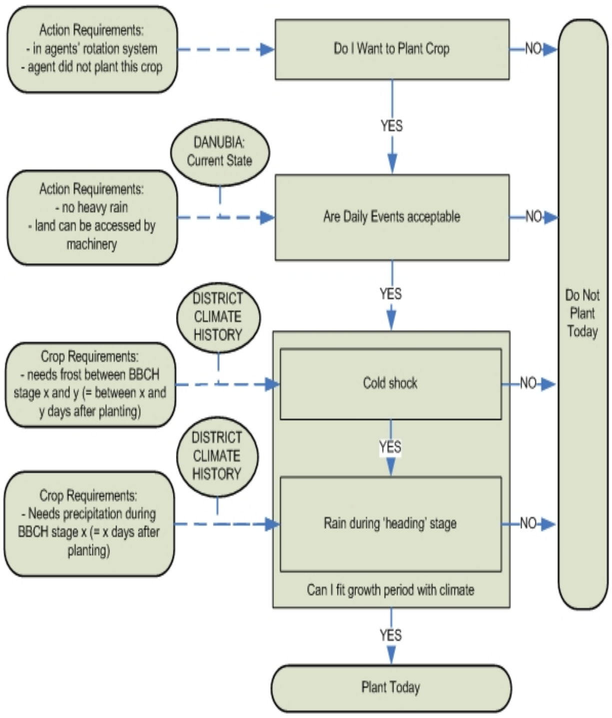

Figure 1: Decision-tree for planting winter wheat

These decision trees shall be improved by combining it with empirical data to strengthen the decisions with inductive facts. To proof the interrelation between weather parameters and management activities, data from the DWD (Deutscher Wetter Dienst) on the daily average temperature and observed development stages of different crops for the period from 1970 to 2003 was used. To find a connection between climate parameters and these requirements the data on the different districts was separated in the following two groups:

First of all the total catchment area was considered as homogeneous, there is no difference between specific districts, climatic zones and elevation.

Secondly for every district it was taken the average value over the period of the thirty years per district. In this case the districts can be compared with each other. The yearly variability was not considered anymore.

This differentiation was taken into account to get a sense about parameters which are hidden in the dataset and are considered as constant, because in the correlation only one parameter the daily average temperature is considered. The advantage is, that later in the result set a correlation value near one shows the secondary role of other parameters which were not considered in the correlation.

These two groups were analysed in three different ways:

- In the first approach several periods of time before the planting day (60, 40, 30, 10, 5 and 3 days) were taken for each crop and the average temperature from each respective period was correlated with the planting day.
- The second approach was based on literature review on phenological stages of natural vegetation where plants and their growing stages were predicted by a specific temperature sum above a specific basis temperature [3]. For this observation, the days with daily average temperature >=5°C from the first of January until the end of February, March, April, May, and June were taken. Then the planting day was correlated with the temperature sum lasting from the first of January until the end of the defined months.
- In the third approach the vegetative start and end were calculated. The value is computed with the average daily air temperature. The vegetative start is the first day in the year, which endures the temperature of 5°C. This is quantified by the following thirty days, which have to fulfil the following term: $\sum_i (T_i - 5°C) > 0°C$ (i= 2, 3...30) (1). The vegetative end is defined as the day where the value is lower than 5°C and the following days fulfil the following condition: $\sum_i (T_i - 5°C) < 0°C$ (i = 2, 3 ...end of year) (2) [4].

This date of the vegetative start or end was correlated with the planting day of the specific crops.

III. RESULTS

Results show that every crop has to be considered separately and the requirements of the different crops on temperature have to be observed in different ways. There are crops which have a low germination temperature, for those the average daily temperature shows no relation with the planting day. In this case the temperature sum in a specific period is more precise.

Sugar beet showed an increasing correlation value with the temperature sum from March until May, where the correlation reached a value of -0.675 at the 0.05 level. The conclusion is that the higher the temperature sum the earlier sugar beet is planted in spring. This is in line with the strategies of farmers to increase the yields by lengthening the growing period of sugar beets. Similar results were found by correlating spring barley and oat with the temperature sum of specific months. The temperature sum until the end of March showed for both highly significant correlation values, -0.586 for oat and -0.729 for spring barley.

On the other hand crops with a high germination temperature show significant correlation results with the average daily temperature of a period before the planting day. For example maize needs a relatively high temperature about 8-10°C [5]. The correlation results showed that there is a correlation at the highest level (0.01) within 10 days before planting, where the temperature was around 10.5°C.

In the third approach the different crops were correlated with the vegetative start or end. In spring the planting of oat and spring barley starts with the start of the vegetative growth. The correlation values of oat, spring barley, and sugar beet are very close together, in a range between 0.505 and 0.653 on the significance level of 0.05.

IV. DISCUSSION & CONCLUSION

The involvement of inductive data is an adequate possibility to improve the heuristic management decisions, based on literature, for the specific development stages of the plants. The correlation results reflect this issue by showing up the connection between the days of planting and the required temperature levels of the different seeds. However, crop management activities are not only influenced by temperature, although this is an integral part of a plant growing period. The farmer has to consider also other parameters like precipitation or day length. In a next step these parameters shall be integrated into the observation, which results in a regression analysis. At the end the regression analysis shall show up risk factors caused by climatic parameters, which might improve the crop management decisions in the agent based model.

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