

Variable rate irrigation

using remote sensing and Fuzzy control system

Ayushi Trivedi^{1*} and Nirjharnee Nandeha²

Department of Soil and Water Engineering, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur 482 009, Madhya Pradesh

Variable rate irrigation (VRI) is a capacity to spatially vary the depth of water application in a field to handle different types of soil, crop, and other conditions. Precise management zones must be developed to efficiently apply variable rate technologies. However, there is no universal method to determine management zones. Using speed control maps for the central pivot is one option. To develop an intelligent fuzzy inference system based on precision irrigation knowledge, i.e., a system that can create prescriptive maps to control the rotation speed of the central pivot. Satellite images are used in such studies because remote sensing offers quick measurements and easy access to information on crops for large irrigation areas. Based on the VRI-prescribed map created using the intelligent decision making system, the pivot can increase or decrease its speed, reaching the desired depth of application in a certain irrigation zone. Therefore, considering the spatial variability in the crop has made the strategy of speed control more realistic than traditional methods for crop management. Therefore, it is possible to affirm that traditional control models used for central-pivot irrigators do not support the necessary precision to meet the demands of speed control determined by the developed VRI systems.

Keywords: Decision making system, Intelligent fuzzy inference system, Remote Sensing, Satellite image, VRI system

THE Food and Agriculture Organization (FAO) of the United Nations estimates that to meet food demands in 2050 agriculture production must at least double or triple in the next 40 years, and 80% of this increase must come from increasing the production. Considering the limited resources of our planet, reaching this goal will be challenging. However, with the growing limitation of water resources, the use of water in agriculture must be more efficient to maintain the current levels of productivity in conjunction with the expansion of irrigated areas. Decisions for irrigation management require taking into consideration inter-related economic, physical, and biological variables, which are frequently difficult to foresee and over which there is little or no control. The decade-long search for

automated solutions to improve agricultural application for more efficient use has resulted in the introduction of several solutions for agricultural inputs to conduct water application with spatial correction. Irrigation systems that operate using variable rate water application are required for a spatial water management to increase crop efficiency.

Decision support systems for irrigation and water conservation are used intensely for minimizing water application and maximizing yield. However, the numerical optimization of irrigation systems is computer-intensive and often requires simplification and discretization of the model. Furthermore, sensorial system and model integration do not reflect the natural flow of the environment, creating significant limitations in performance. Control

systems also do not reflect or satisfy the requirements of the final users due to the lack of domain knowledge capture. The use of advanced control techniques is a promising possibility. The final challenge of an environmental and agricultural support system is to overcome the uncertainty related to data quality and difficulties in remote sensing of large areas. Moreover, the inter-related economic, physical, and biological variables are multi-attributed vaguely and in subjective terms.

A neat approach to deal with such uncertain situations is found in the fuzzy set theory, which has now reached a mature state for expansion and application. Fuzzy logic can analyze the imprecise information and is efficient in decision making for vague and uncertain phenomena. In agriculture, the interface of these

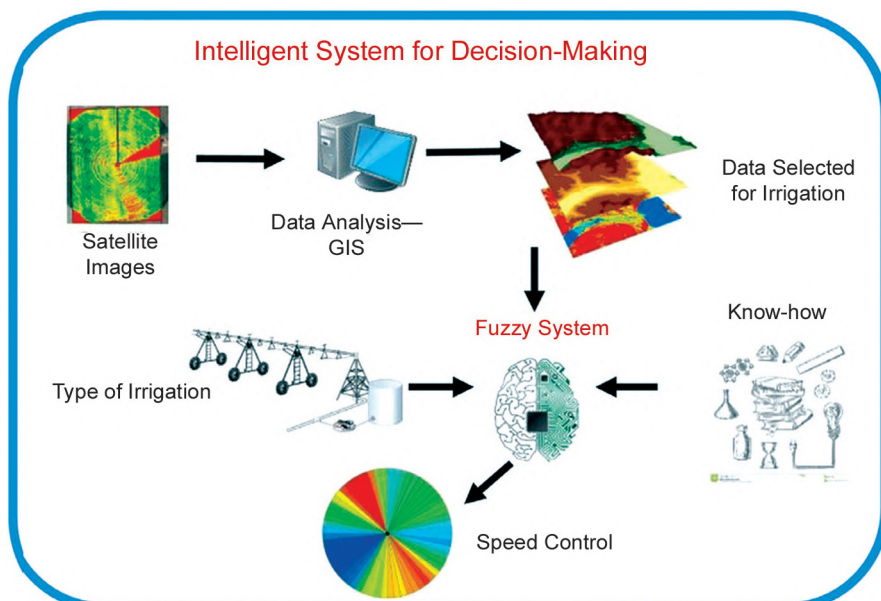


Fig. 1. Variable rate irrigation system (VRIS)

systems allows a natural and straightforward use, as a planning tool for the manager and farmer. In irrigation systems, the interaction between components is not always accurately defined. Fuzzy logic can be used in such systems for extracting inferences from an inaccurate input and for solving problems in this. An irrigation system based on the fuzzy logic with simple rules is more attractive to most farmers since these systems do not require a precise measurement or a precise model, which may be very complicated and require considerable funds, resources and development time.

Variable rate irrigation system (VRIS)

An intelligent irrigation system

was developed by following the structure shown in Fig. 1. The structure of the proposed system allows the elaboration of the management map in a systematic, autonomous, and automatized way to control the irrigation system.

Data Required

Normalized difference vegetation index (NDVI) and canopy temperature

These indexes have been used to estimate several vegetation patterns, such as leaf area index and green biomass quantity, as well as in the evaluation of soil use and the maintenance and recovery of degraded areas. Information from satellite images and values from the

normalized difference vegetation index (NDVI) reading, which is an essential parameter for irrigation maintenance, were used and adjusted according to local conditions. Irrigation management through the plant shows the complexity inherent to the visualization of the symptoms of water deficit, which are difficult to detect.

Canopy temperature and infrared thermometry was used to relate the development of the crop through remote sensing. A plant under water stress has decreased transpiration and would typically show a higher temperature than a plant that is not under stress, a trait used as a powerful tool to monitor and quantify water stress. Canopy temperature increases when solar radiation is absorbed, but it cools down when the latent energy or transpiration is used for evaporating water instead of cooling plant surfaces. Further, algorithms based on canopy temperature were strongly correlated with quantifiable results from crops, such as yield, water efficiency use, seasonal evapotranspiration, leaf water potential at noon, irrigation rates, and damage caused by herbicides.

Satellite Imagery

The i-ekbase is regularizing satellite remote sensing for all purpose precision agricultural monitoring on a mobile device, for greater benefit to global agriculture community, and for increasing

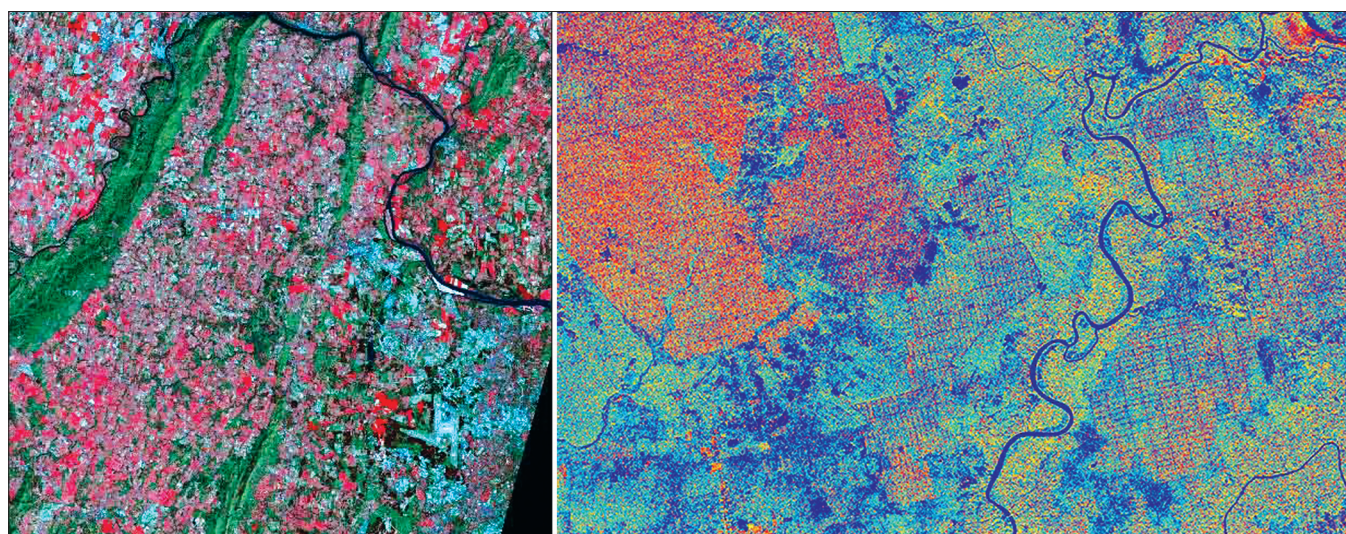


Fig. 2. Images from the area under study

Table 1. Data exported by the i-ekbase web tool

Lat	Long	Canopy Nitrogen (%)	Leaf area index (m ² /m ²)	NDVI (%)	Biomass (tn/ha)	Soil Salinity (dS/m)	Soil Moisture (%)	Canopy Temp (°C)
25.2464	64.0157	0	0	13.76	0	3.98	15.852	37.348
25.2464	64.0156	0.05	0	15.4	0.24	3.29	14.219	35.81
25.2464	64.0155	0.73	0	15.89	0.55	3.59	12.76	35.07
25.2464	64.0159	3.87	0	23.98	0.96	3.16	11.561	39.39
25.2464	64.0158	4.56	0	29.68	1.19	3.01	10.87	39.63
25.2463	64.0162	7.1	1	33.78	1.782	2.77	8.765	42.35
25.2463	64.0162	9.19	1	38.98	1.98	2.58	7.503	37.897
25.2463	64.0161	12.769	1	42.87	2.132	2.38	5.184	40.516

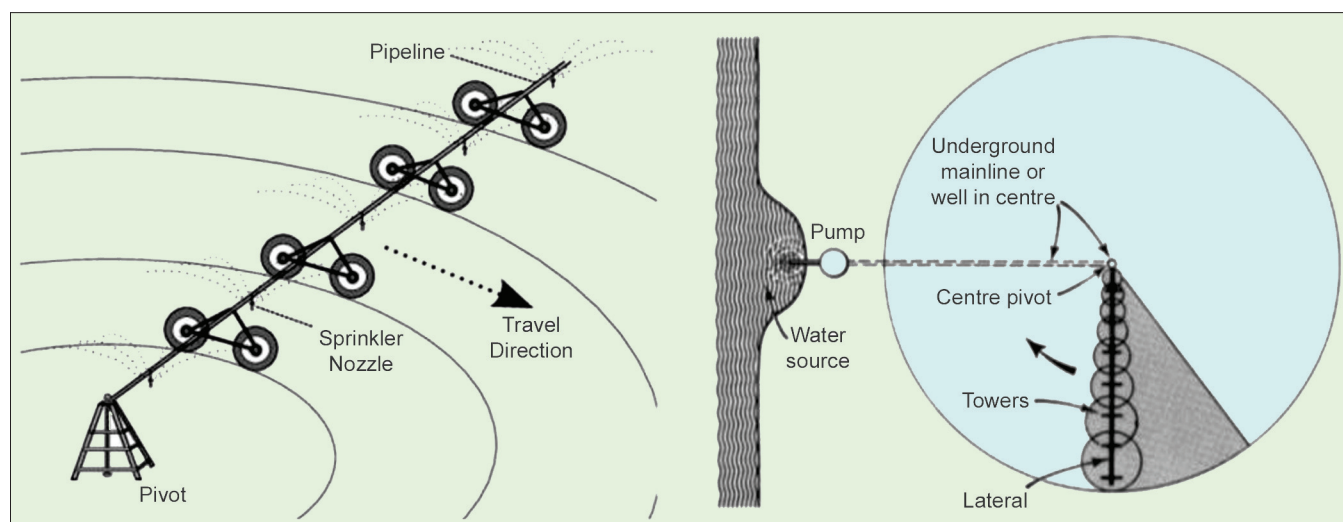


Fig. 3. Structure of a central pivot

agriculture business profitability. The system services provide weekly or daily large area-wise resource management map products, including normalized vegetation index (NDVI), soil moisture, biomass, surface temperature, vegetation landscape maps for supporting remote digital scouting, large area-wise farm monitoring and decision support system, and rapid intervention of a management issue.

Herein, we used the i-ekbase system for capturing timely remote sensing imagery on the study site using Landsat (with a spatial resolution of 30 m) and Sentinel (with a spatial resolution of 10 m) satellites. Data were captured for 12 months for developing the experimental system (Fig. 2, Table 1).

Fuzzy systems

Over the last 20 years, fuzzy systems have attracted considerable attention and have met great applicability in the agricultural domain, helping farmers to make the

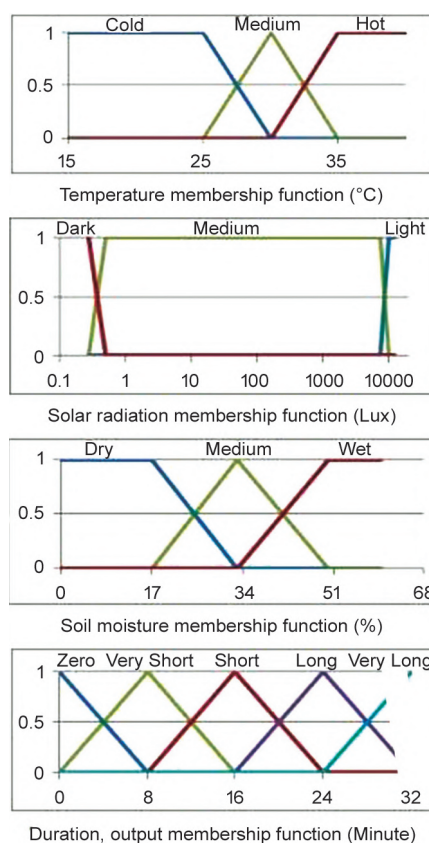


Fig. 4. Inputs and output membership functions

right decisions for their crops. Due to the nature of the management of the study area, fuzzy systems are used herein to aid irrigation decision-making. Because a farmer's decisions are purely intuitive and knowledge based gained over years of work, we chose not to describe the way the farm works explicitly.

The information extracted after pre-processing remote sensing data was NDVI, canopy temperature, and upper layer soil moisture. These values are the input data set for the fuzzy system, which is capable of inferring percentages for the central pivot rotation speed motion. The input set for the intelligent fuzzy system is the analyzed and processed data on canopy temperature, moisture close to the soil, and NDVI. The input, was organized according to the linguistic variables of the fuzzy system and separated by tones for better visualization. Due to the nature of the central pivot speed control equipment, the output given by the fuzzy system was in

percentage values (Fig. 4).

Analysis of the input data identified the existence of two broad areas with lower leaf development, which could indicate a lack of water for development. After processing input data, the intelligent irrigation system showed these areas of lower leaf development in a more intense red tone. This indicates that the pivot must reduce its speed, thus increasing the water layer in that specific location, because the rotation speed of the pivot determines the level of the water layer applied. A thinner water layer is applied with higher

speed and a higher application of water in the soil occurs with lower rotation speed.

CONCLUSION

The implementation of fuzzy logic decision support system was successful to develop prescription maps for VRI with central pivots. However, a broader and commercial application will depend on the integration of data collection systems, management strategies, and hardware control. In other words, the fuzzy logic model performed as expected, providing excellent results. However,

the reliability of data sources (NDVI, surface soil water, and canopy temperature) to develop a reliable prescription map is the scope of future study. The future study will focus on the field implementations and determine whether any additional data (different types of data, high quality data, and/or more frequent data) will be required for developing the map.

¹Dept. of Soil and Water Engineering, JNKVU, Madhya Pradesh, ²ICAR-CIAE, Bhopal, *Corresponding author's e-mail: ayushikhandwa532@gmail.com



HANDBOOK OF HORTICULTURE

VOLUME 1 & 2



The Indian Council of Agricultural Research has brought out the Second enlarged and revised edition of the Handbook of Horticulture. Horticultural crops are gaining more and more importance as they have been instrumental in improving the economic condition of the farmer and contributing significantly to the national GDP. This new revised edition has been divided into 2 volumes – Volume 1 contains General Horticulture and Production Technologies (Fruit, Vegetable and Tuber crops) and Volume 2 has Production Technologies (Flower, Plantation, Spices crops and Medicinal and aromatic plants), Plant Protection and Post-harvest Management. The earlier chapters have been thoroughly revised and new chapters have been added. It is hoped that the readers will find this Second edition more useful and informative.

Technical Specifications

Pages : i-xxxiv + 1-682 (Vol. 1)
i-xxiii + 683-1218 (Vol. 2)

Price : ₹ 2000 (Vol.1 & 2) • Postage ₹ 200 • ISBN : 978-81-7164-187-1

Copies available from:

Business Unit

Directorate of Knowledge Management in Agriculture (DKMA)

Indian Council of Agricultural Research

Krishi Anusandhan Bhavan, Pusa, New Delhi 110012

Tele: 011-25843657; e-mail: bmicar@icar.org.in, businessuniticar@gmail.com

