Review Article

A Review on Remote Sensingas A Tool for Irrigation Monitoring and Management

ABSTRACT

Remote sensing has played a vital role in advancement of agriculture and is effective technical method for agriculture crop management. It is a technology which acquisiteinformation regarding objects on earth surface as well as atmosphere from a distance without being in contact with the object. Researchers have proved its high potential with accuracy in the field of agriculture. After various experiments, the qualitative and quantitative assessment of soil, crop and atmosphere demonstrated the better understanding between the crop and its management practices. The collected spatial and temporal data via various passive and active sensors has been utilized not only for morphological study but also for monitoring the vegetation moisture content. The paper reviews about the potential studies carried out to investigate the water content in plant to make use in irrigation management.Diverse spectral reflectance indices have beenmentioned from which special emphasis on NDWI has been given.It is an index which is used in remote sensing to assess the crop water status and can be utilized in efficient operation of irrigation to improve water use efficiency (WUE) in agriculture. In order to fill the gap between various researches and present practices. This paper firstly identifies areas where researches and techniques have real-world application. Next, it identifies actual issues that remote sensing could address and solve with further research and its related development. Any possibilities to effectively manage water uses specifically in irrigated agriculture, as freshwater become an increasingly precious resource. Using the fast, impartial and reliable information offered by remote sensing is a significant difficulty in the field of water resource management.

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Keywords**:**Precision Agriculture,Remote Sensing, NDWI, Water use efficiency (WUE)

1. INTRODUCTION

The emerging demand of food grains for present as well as future generation, it is important to manage our resources especially water as only 3% of total water on earth is fresh water. The sudden climate change made it compulsory to conserve water in sustainable, efficient and precise manner.In crop production, among various management practices like nutrient management, disease and pest management, irrigation management plays a vital role and hence a large amount of water is used for the production of cropupto 30-40% (Secklar et al.., 1998).It is not an easy task to manage such situation with

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high degree of pollution with environment degradation, the possible way to overcome will be by incorporating new technologies togather precise information of water resources and its reliable management practices with accuracy.Conventional irrigation practiceinvolved the irrigation application based on either set schedule or visual observations. This approach has lead to under or over-irrigation which could be harmful to crop also the wastage. Presently, Remote Sensing emerged as an automated technology with acquisition of spectral data based on reflectance at varied wavelength and provide us readily available vegetation, land cover, or soil imagery. It makes it more accessible to the scientists to cover large area with site specific information by satellite constellations, MODIS (Moderate Resolution Imaging Spectroradiometer), LANDSATs, MERIS (Medium Resolution Imaging Spectrometer), AVHRR(Advanced Very High Resolution Radiometer) and aerial photography, to capture and analyzefigures, based on which it characterizes thevegetation (Ozdogan et al., 2010).Thespace-borne sensors are capable to capture data of million hectares of area at a time and provide particulars related tofarmers field or nearby water resources such as river basins, irrigation channels to fasten the decision making.

Remote Sensing collectively gathers spatial (varied resolution) and temporal data(satellites revisiting intervals of 15-25 days) by using sensors that senses multiple spectral bands of electromagnetic spectrum. The specific wavelengths of electromagnetic spectrum are found to be sensitive towards the moisture content that makes possible to predict the moisture content in crop plant(Peñuelas et al., 1993; Stimson et al., 2005). The reflectance values integratein such a manner to give various indices viz. vegetation indices (NDVI), soil adjusted indices (SAI), Chlorophyll indices (CI), water indices (WI) etc.These reflectance-basedindices have numerous implementations, NDVI is commonly used in agriculture for various purposes (Calvao and Palmeirium, 2004; Wallace et al., 2004)like assessing the condition of vegetation (Rouse et al., 1973), Normalized difference water index (NDWI) obtained by combining green spectral wavelength reflectance and near infrared reflectance been used in agricultural, hydrological and environmental monitoring. NDWI estimatesmoisture contentthat assistspractitioners to understand the dynamics of water and its impact on the crop yield. It facilitatesin determining the exact amount of water required by the plant to avoid excess and deficit use of water. Similarly, water stress in crop can also be identified and utilized for précised water management.This paper consists of the information about the remote sensing and NDWI application for irrigation management. The initial part provides the basic information of remote sensing highlighting normalized differential water index. Finally, discussion about the applied areas of water index for irrigation management inrelation with the water content estimation in crop.

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2. REMOTE SENSING: AN INTRODUCTION

Remote sensing collects spatial and temporal data and provides an information of entire land cover and with GIS (Geographic Information System) it outlay the data in the form of imagery (single spectral or multiple spectral imagery). It provides timely and repetitive data to continuously monitor the changes in the vegetation, atmosphere or environment (Justice et al., 2002). Now the question arises in what form does the data is collected? The answer is reflected, dispersed or refracted light provides the information about the earth surface and different targeted object in the form of reflectance.The electromagnetic spectrum (Visible, NIR, SWIR and microwave regions) hits the objects and response differently, that distinguishes the soil, vegetation, water and other entities present on earth. Remote sensing has various applications in agriculture like weather forecast, land cover, land mapping, monitoring disease and pest and by combining it with the simulation models it manifests in yield prediction. It is a cost-effectivealternative for acquiring information of large geographical area (De beurs and Townsend, 2008). Automated approaches are included in the remote sensing for the visual interpretation of satellite data (Thiruvengadachari, 1981; Kolm and Case, 1984; Keene and Conley,1980; Haack et al., 1998).in visible and NIR regions of EMS (Electro-magnetic Spectrum), irrigated field exhibit high spectral difference from the harvested as well as fallow lands, which is advantageous for the researches related to irrigation. Even research by Thiruvengadachari in 1981, showed that although it is more difficult to differentiate different crop kinds, irrigated lands by surface water from ground water by visual interpretation through single Landsat Imagery. The EMRreadings obtained which is used in vegetation indices. That are derived by adding, subtracting, dividing or multiplying the reflectance of specific wavelengths can be very helpful in discriminating crops but also differentiating based on the irrigation sufficiency or deficiency. Although interpretation of satellite images visually is helpful, but recent works focused on digitally clarification of images, because processing time is faster and mapping expenses are less making it more cost effective.The classification based on index values will be more advantageous as they eliminate the surrounding mixing of data and being precise in nature. The unsupervised learning, multiple- stage classification (Thelin and Heimes, 1987; El-Magd and Tanton, 2003), flow chart classification (Simonneaux et al, 2008), clustering (Thelin and Heimes, 1987; Eckhardt et al., 1990; Kauth and Thomas, 1976), density slicing classification (Ozdogan et al., 2006; Manavalan et al., 1995; Starbuck and Tamayo, 2007) are some methods used for classifying the digital images. The plant type, water content, pigmentation, chlorophyll content are some intrinsic factors that create variation in reflection pattern of light that causes variation and eventually classify the crop and their conditions. The following spectra of electromagnetic radiation and factors affecting the reflection of spectrum (Bal, et al. 2021)

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(i) Visible region (350nm to 750nm): leaf pigmentation affects the reflection.

(ii) Near infrared region (750nm to 1300nm): cell structure of plant affects the reflection; the total internal reflection is the major reason for maximum reflectance at NIR.

(iii) Shortwave infrared (more than 1300nm): water content in plant affects the reflection

3. NORMALIZED DIFFERENTIAL WATER INDEX (NWDI)

There are different indices like NDVI (Normalized differential vegetation index), Chlorophyll index (CI), SAVI (Soil Adjusted Vegetation index), WI (water index) etc.these indices have various application in mapping, drought monitoring and assessing vegetation health as well as productivity (Doraiswamy et al., 2003; Ferencz et al., 2004; Prasad et al., 2006). NDWI is one index in remote sensing used to evaluate the presence of vegetation water content. It is commonly used in agriculture to help monitor and quantify changes in water content in crops. The vegetation spectrum reflectance at 0.9 to 1.3µm wavelength band is very sensitive towards the water content in the leaf (Lillesaeter, 1982). High water content in vegetation cause scattering and absorption of spectrum enhances at specified wavelengths.The emission value not only contains the reflective value of target object but contains disturbances or surrounding area and noises to nearby objects. NDWI is less sensitive towards the atmospheric disturbances or noises in reflectance (Gao BC, 1996). This index doesnot completely remove the soil reflectance noise but it provides accurate value of water content present in the canopy.It differentiates the irrigated and non-irrigated areas in the satellite images. The multi-temporal NDWI features such as its range and maximum value are set to thresholds to distinguish the crop fields. If the NDWI observations are at hand from several years and of same season, it is possible to identify crops and their changes in irrigated areas. The value of NDWI ranges from -1 to +1.Higher value of the NDWI indicates a higher water content in the vegetation, which is important information for monitoring crop health, irrigation needs, and also drought conditions. It assesses the water content and as per the requirement of water by plant the irrigation can be planned.

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NDWI Computation

Normalized difference water index (NDWI) can be formulated by using the two spectral bands near-infrared region (NIR) and green bands (visible region).

$$\text{NDWI} = \frac{(\text{Green}-\text{NIR})}{(\text{Green}+\text{NIR})}$$ (U.S. Geological Survey)

This normalization process helps to minimize the impact of atmospheric effects and sensor noise on the NDWI values.

Also,

$$\text{NDWI} = \frac{\{R\,(0.86\mu m)-R(1.24\mu m)\}}{\{R(0.86\mu m)+R(1.24\mu m)\}}$$ (Gao BC, 1996)

Where, R(0.86µm) is the Reflectance at 0.86µm wavelength

R(1.24µm) is the reflectance at 1.24µm wavelength

The analysis of water content in the vegetation can help in making decision related to when and how much irrigation is needed by the plant. There are various studies and researches carried out in respect to find out the moisture content in the crop, some of them are mentioned in Table 1

Crop Monitoring:

Irrigation system administrators should ideally incorporate routine performance monitoring into their management strategies. In the section of operations, this is covered in more detail. Sometime a problem's nature or intricacy calls for a more thorough diagnosis. To find performance constraints in such cases, consultants or researchers are contacted. When consultants are aware of prospects, satellite remote sensing, particularly in vast complicated areas, can be cost-effective tool for diagnosing and determining the performance of irrigation.

The timely data collected by satellites of different resolution capacity (Landsat, CARTOSAT-2, Resourcesat-2 etc) with GIS, presented it in imagery form and the data is converted into NDWI value-based imagery. Thus, comparing different crops and classifying them on the basis of NDWI gives comparative information about vegetation. The rays of electromagnetic spectrum are able to penetrate the object and provide information regarding intrinsic factors of crop. Such as, relative water content of crop which is a best yardstick to determine moisture stress status, as stated by Slatyer, 1967 and Chaves et al., 2002 at different stages of crop growth. The hyperspectral characterization, differentiation and mapping of crop according to its biochemical and biophysical property (Thenkabail et al., 2013) is highly beneficial in studying the innate properties. These relative details about crop provides knowledge wide range of

Table 1. Water index and their association with water content in diverse plant species.

Water Index	Study and conclusion	Reference
NDWI	The water content of vegetation and observed at field and laboratory and found NDWI	Gao, BC, (1996)

	highly associated with water content of plant.	
NDWI, SRWI and PWI	Used MODIS (satellite spectrometer and stimulated different models to evaluate the water content in vegetation and found the sensitivity of indices in correspondence to the biomass thickness of leaf, and LAI.	Zarco-Tejada and Ustin (2001); Zarco-Tejada et al. (2003).
NWI-1, NWI-2, NWI-3 and WI	Demonstrated the potential association of NWI-3 with leaf water potential (ψ_{leaf})	Gutierrez et al.(2010)
NDWI and NDVI	The satellite imagery (Landsat) based on NDWI proved better for mapping of vegetation moisture content with r^2=0.44-0.68 on corn and soybean crop.	Jackson et al. (2004)
WI, NWI-1, NWI-2, NWI-3 and NWI-4	The WI and NWI-2 were observed to have maximum variability with grain yield and biomass yield of 92% and 78% respectively under varied IW: CPE levels and also these indices proved to be better for yield prediction in wheat	Bal et al. (2021)

figures like water availability, nutrient stress, moisture stress, pest and disease infestation indicating crop health status which results in efficient monitoring and mapping of crop.

Drought Detection and Irrigation Management

Remote sensing provides informative data not only to monitor crop but also diagnose stress in the crop (Kingra et al., 2016). The spectral reflectance pattern results in detection of water stress in crop (Menon, 2012). When it comes to irrigation management the question arises when to apply? How much to apply? How to increase the efficiency of human and cover large area? The answers to these queries are provided by many scientists Peñuelas et al., 1993; Stimson et al., 2005; Serrano et al., 2000by working on different crops and spectral indices, they registered relation between water content in plant and spectral indices (water indices).Its vegetation indices become less sensitive to soil background reflectance and atmospheric disruptions like SAVI (Soil Adjusted Vegetation Index) or SARVI (Soil and Atmosphere Resistant Vegetation Index), the application of vegetation indices can be improved. The complete review on this is mentioned in detail by Rondeaux et al., 1996.The value of NDWI indicates water stress and sufficiency, high values indicate the water sufficient condition and low value shows water stressed

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condition. This water index is the best solution to help farmers, respond to water stress more effectively. The use of remote sensing gives promising results. The involvement of aerial vehicle or drones,either automated or manually controlled in remote sensing for immediate action in irrigationhas better result and provide well timed irrigation management.

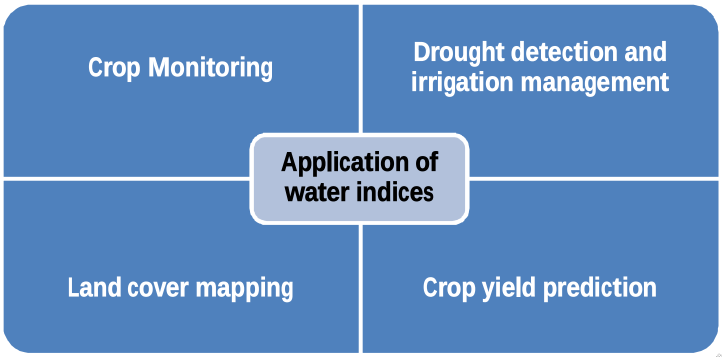

Fig.1 Application of remote sensing and water indices

Crop Yield Prediction

Modeling crop growth simultaneously is made appealing by the idea of incorporating remote sensing data into mathematical/ physical agricultural yield models (Bouman, 1992). For instance, evapotranspiration from crop and LAI from remote sensed data were utilized by Moran et al., 1995 to update the parameters of a field-scale crop simulation model for yield based on physiological characters. Simplified statistical relationships can be employed in their place, if such crop growth models or input data, they require are unavailable. In the heading stage of crop, single data NDVI pictures have proven to be very profitable (Murthy et al., 1996; Thiruvengadachari and Sakthivadivel, 1997). Using these crop yield models for estimating the crop yield in advance cab be very helpful in deciding the crop and its management to make agriculture a beneficial occupation with sustainable resource management. Remote sensing by using satellite data can also help in yield prediction (Doraiswamy et al., 2005; Bernerdes et al., 2012). Remote sensing data have shown a major statistical and empirical relationship with crop yield and water indices to predict yield (Bal et al. 2021). Peñuelas et al. (1993) usedwater index in predicting the grain yield of different genotypes of wheat under sufficient and deficit irrigation conditions, and Prasad et al, (2007)presented the yield for wheat (winter wheat) in rain-fed condition using the Normalized Water Index (NWI) and Water index (WI) manifesting water stress can negatively impact crop growth and production these spectral indices can predict the yield and benefit the farmers (the prime beneficiary).

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Land Cover Mapping

The mapping of the characterized objects on the earth surface is best source to observe and asses the large area in short time. These satellite data-based images are beneficial for visual interpretation due to their spectral transformations (Ozdogan et al., 2006; Eckhardt et al. 1990; Pax-Lenney et al., 1996; Kauth and Thomas, 1976; Starbuck and Tamayo, 2007). In particular NDWI proves to be and indispensable in identifying the irrigated areas and differentiate between the irrigated and non-irrigated conditions. Also, to identify and map different types of land cover, such as crop lands, wetlands, and forests after eliminating surrounding noises or disruptions of soil, surrounding or atmospheric disturbances.NDWI which eliminates majority of disruptions and provide precise values indicating the crop status with regard to moisture status in crop is a good tool for diagnosing the irrigation need. The remote sensing data-based image that locates the distinctive areas and classify the areas according to the stress conditions signifying the water need places. NDWI that shows the water content in plant makesit easy to find the water stressed condition in plants and mark the irrigation scheduling. Anderson et al. (2004) used the ASIRIS an air-borne imagery for soybean and corn to estimate the water content in crop. In summary, NDWI is a valuable tool for farmers and researchers to understand the water status of crops, which can have a significant impact on crop health, yield and overall food production.

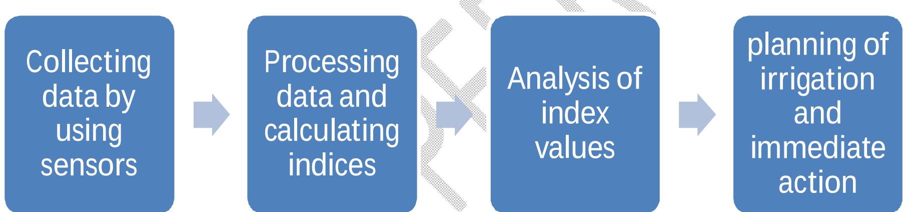

Fig. 2 Series of collection and analysis of data

4. CONCLUSION

Conclusively, remote sensing provides vastly applied data forclassifying the crop and detecting the crop water status which is useful in diagnosis of water stress conditions and make management of irrigation easy. The timely monitoring of crop health and effective measure to be taken with precision. Reflectance based NDWI value gives information regarding the moisture availability that is used in making decision in water stress management of the crop. The researchers have recorded the correlations of spectral indices with water content in crop, LAI, grain or biomass yield or other crop factors.Thus, NDWI gives comparative value of water content so, there is a need of more researches to be carried out for several years and for similar season to estimate the threshold value for its practical application in agricultural irrigation.

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