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A future Demand Side Management (DSM) opportunity for utility as variable renewable penetrate scale up using agriculture.

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1. INTRODUCTION

- Energy demand management, also known as demand side management (DSM), is the modification of consumer demand for energy through various methods such as smart metering, incentive based schemes, payments for turning off loads or rescheduling loads.
- Electricity use can vary dramatically on short and medium time frames, and the pricing system may not reflect the instantaneous cost as additional higher-cost that are brought on-line. In addition, the capacity or willingness of electricity consumers to adjust to prices by altering elasticity of demand may be low, particularly over short time frames. In the scenario of Indian grid setup, the retail customers do not follow real-time pricing and it is difficult to incentivize the utility companies for continuing the peak demand supply. Can renewables provide a solution to meet the peak demands.

OBJECTIVE: This experiment tries to show how agriculture and climate services could make solar integration more affordable and efficient. Availability of energy services could facilitate sustainable GDP growth if one integrates it with both climate and financial literacy and the steps are described in the poster.

2. METHODOLOGY

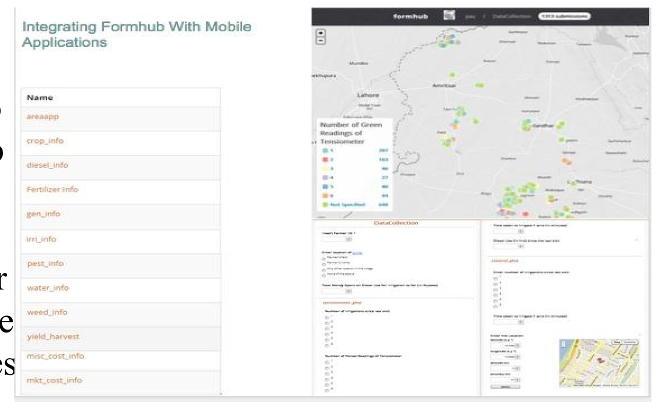
2.1 Solar Installation

1 MW grid connected solar PV plant with Smart Tracking:

Electricity generation and distribution is regulated through government policy. In the present context; through negotiations with the state government, state distribution company and the electricity regulator a 1 MW grid connected solar PV plant has been approved in principle for the wadepally village in the Telangana state of India. The project has been declared eligible for 30% subsidy on capital cost by the government. The distribution Company has agreed for a Power Purchase Agreement at a tariff of INR 5.6, which is financially viable. Also the land is provided by the village administration and in return the Distribution Company will keep the village feeder live for the whole day, something which was not presently happening.

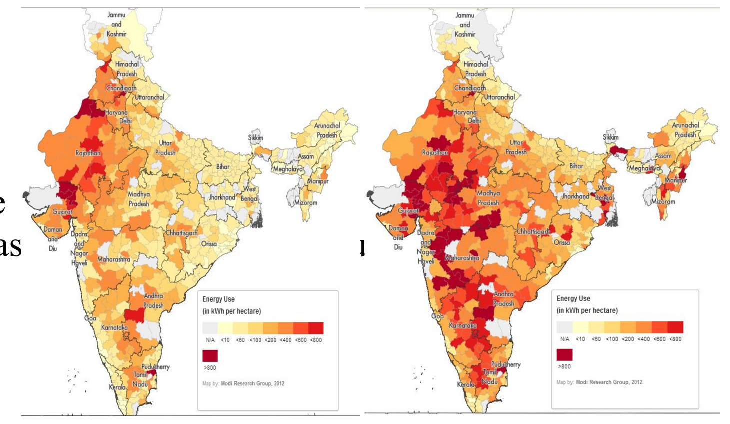
Installing VFD based Pumps: Ground water level in this region varies with season and also during a pumping cycle. Running the pump sets at constant speed is highly inefficient and even leads to pump failure due to prolonged dry runs in certain instances. It has been proposed to replace the present old and inefficient pumps with energy efficient solar pumps with Variable frequency drive (VFD), Voltage stabilization and auto cutoff features. The solar pumps will be grid connected and be provided with net metering facility, which will enable to optimize the operational performance and maximize profit.

2.2 Managing the Agricultural Output By Running Extension Programs in coordination with utility.

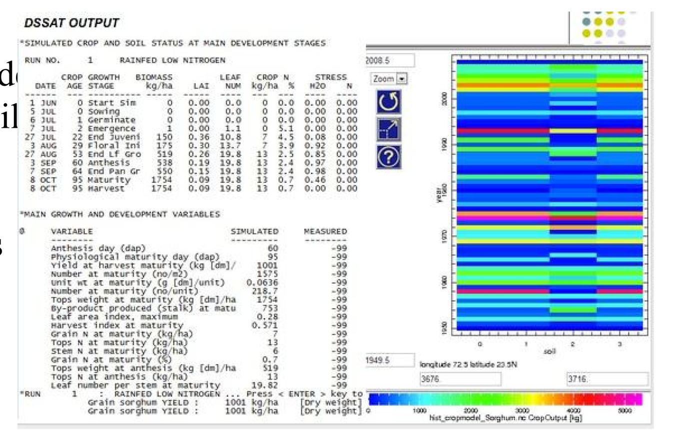


FORMHUB (https://formhub.org/) is an app that was developed by to collect data from the field. The application provides flexibility to collect data from the field. The following image shows use of formhub for collecting data from the field. On the left all agriculture related information are collected during pre and post harvest. Also as part of the experiment we are experimenting on organic vegetable crops under close supervision of accredited agencies (eFRESH) so that, the produce is continuously available for a single purchaser through the crop cycles.

2.3 Integrating Physical Models Like Crop Models and Energy Models.

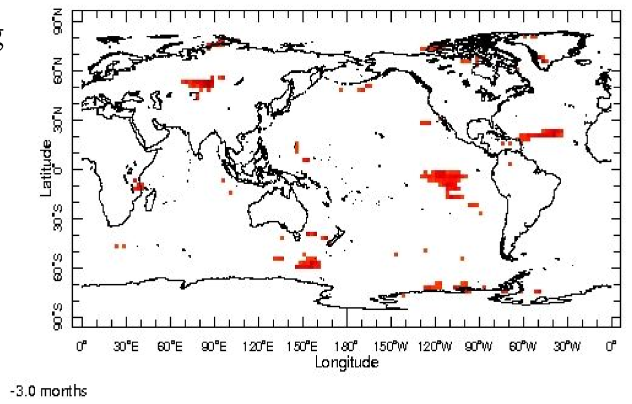


Energy Models: With the growth in population, there has been constant increase in demand for food and energy. Availability of energy sources helped farmers to pump out groundwater to meet the growing demands for food, but years of pumping has resulted in drop in average depth of groundwater. This resulted in increase in demand in energy and stress in agricultural output. A model was energy used for groundwater pumping for each district based on information from census data in India. The following maps show the energy used in winter and monsoon seasons. (http://ag-energy.modilabs.org/India/)

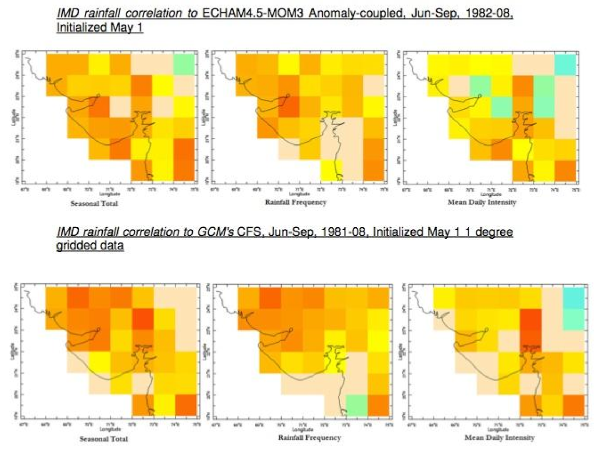


Crop Models: A Crop Simulation Model (CSM) is a simulation model that helps estimate crop yield as a function of weather conditions, soil conditions, and choice of crop management practices. The Decision Support System for Agrotechnology Transfer (DSSAT) Version is a software application program that comprises crop simulation models. A MVC web application was developed to integrate the field data collection with crop modeling. (http://pred.iri.columbia.edu:8080/weatherprediction/)

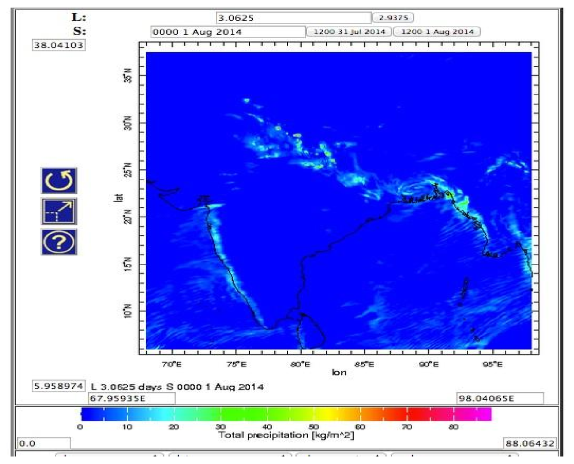
2.4 INTEGRATING CLIMATE AND WEATHER PARAMETERS



KNN on OLR: The total seasonal rainfall was calculated using k-nearest neighbor approach on outgoing long range radiation. The following image shows the regions around the world where OLR has rank correlation of more than 0.35 with the monsoon anomaly rainfall in the state of Punjab, India. Research suggests that OLR could be one of the predictors to Indian rainfall. The model showed skill in predicting seasonal monsoon.

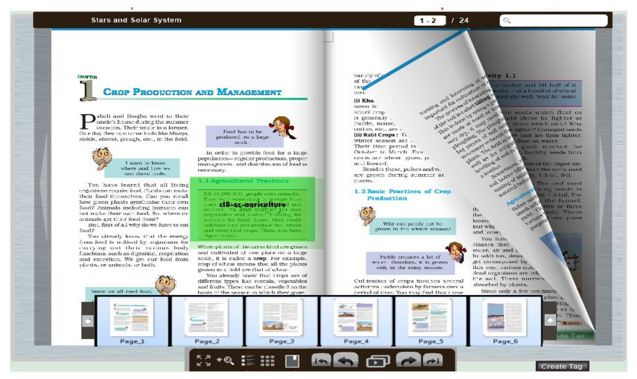


GCM DOWNSCALING: To understand the temporal pattern of the rainfall, the approach uses NHMM (Non homogenous Markov Models) on GCM's. This is usually a seasonal scale prediction and used to understand how the rainfall will behave in the following season by training the model for 30 years. This downscaled models can be integrated with crop models and energy models as described above to build up a stochastic scenario to be used by policy makers to plan for the future.



WRF Predictions: The image shows the short term prediction of three day scale that uses the WRF product. This message is given to the farmers so that they might not irrigate or put fertilizer in the field. In order to disseminate the forecasts to the farmers, an ensemble mean was calculated over the gridbox for which the farmer has requested for forecasts. The ensemble mean is calculated by averaging over the three day forecasts from the corresponding events.

2.5 Educating Farmers About The Impact of Climate Change, Cropping Patterns Changes, Best Agricultural Practices And Energy Conservation Techniques



MYOLIVEBOOKS: The objectives of this project is to bring in local institutes and researchers in the field of water, energy and agriculture in a common platform to share localized information and technology knowhow. The individual in the field can subscribe to the content on information pertaining to agriculture, climate, water & energy saving technologies. People can also take a certification course and thus be able to apply for water saving technologies. Keeping this in mind the main activities are 1) Engaging water experts in creation of content and courses about water saving technologies, share videos on their water related research, host online talks and events. 2) Locating end users, namely farmers and collaborate with local partners like NGO's and private companies, to help educate them. 3) Integrate a software rating tool to understand the best water saving technologies provided by the teachers in a collaborative environment. (http://www.myolivebooks.com/)

FarmerFriendApp: The app could be accessed by the farmers or extension workers on a mobile device with internet access. The users will be able to access a variety of data like crops, crop types, farmer information, weather and climatic information and other relevant data on their mobile phones without being concerned about the source of data. Automated recommendations are generated using ontology and RDF concepts that will help the users get the frequently occurring queries answered much more quicker and easier. The system is capable of answering queries like disease prevention and pest cure based on the symptoms obtained by selecting type of crop, soil etc.

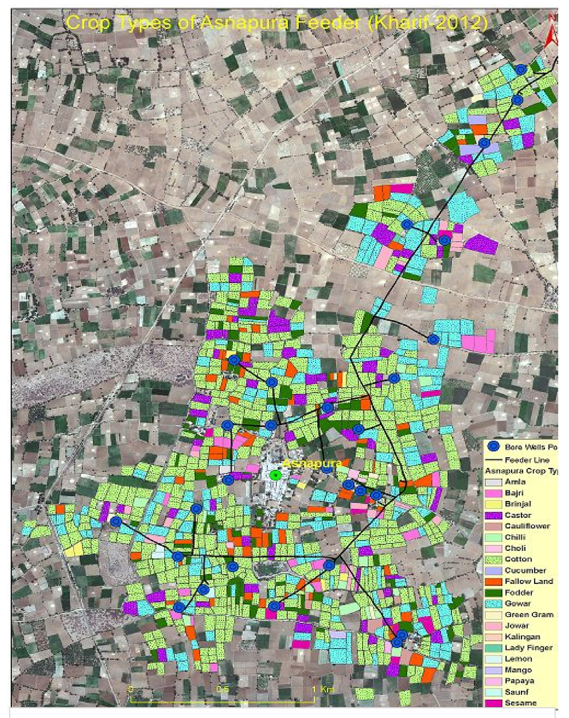
REFERENCES

Devineni, N., S.Perveen & U.Lall., "Assessing Chronic and Climate Induced Water Risk Through Spatially Distributed Cumulative Deficit Measures: A New Picture Of Water Sustainability In India, Water Resources Research,2013, accepted"

Hansen, J.W. and A.V.M. Ines. 2005. Stochastic disaggregation of monthly rainfall data for crop simulation studies. Agric. Forest Meteorol. 131: 233-246.

Kocaman. et al., 2004. A stochastic model for a macroscale hybrid renewable energy system. Renewable and Sustainable Energy Reviews.54, Pages 688–703

3. PRELIMINARY RESULTS

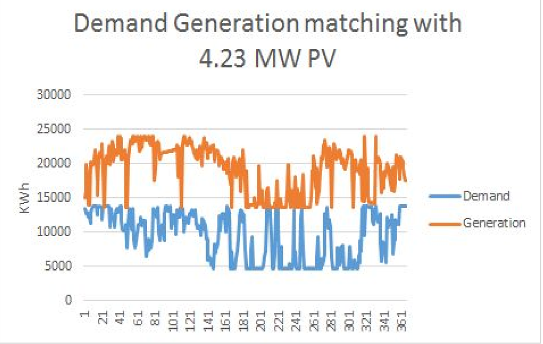


The model was run for the cropping pattern and is plotted against the utility values of the feeder in a village in North Gujarat. This took into consideration, the cropping pattern and climatology of the region. The following image shows the village feeder. In this scenario the correlation of the utility values with the energy model is 0.64 considering the factor of 33% agriculture and pumping efficiency. So the model could be used for planning solar infrastructure in rural villages.

Solar Power Requirement Calculation

-Naive Approach

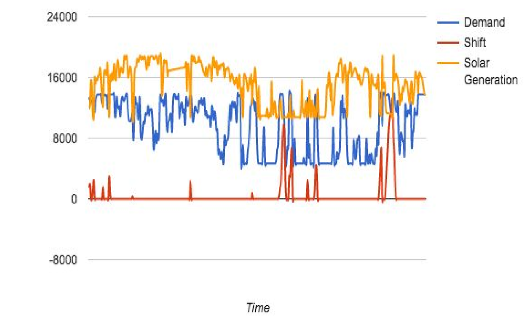
Electricity generation data from a 1 MW solar PV plant and electricity demand for irrigating the farms fed through the feeder, for the year 2012 were compared. The following image shows the demand and generation curve for an optimal 4.23 MW generation over the feeder to meet the demand peaks of the year.



-Linear Programming Model For Demand Shift Calculation

The required solar panel area is calculated considering perfect information about the solar power generation (i.e there is no uncertainty about the solar radiation and how much solar radiation will be observed throughout the year is known in advance) and schedule activities in the field based on this information to reduce the demand. Linear programming (LP) models are constructed to determine the optimal solar power capacity.

In the models below, the parameters and the decision variables are listed as below:



Parameters:

D_t= Demand at day t.

S_t= Solar power output of 1 MW station at day t.

Decision Variables:

M= Capacity of the required power station.

P_t= Amount of demand postponed to tomorrow at day t.

Objective:

minimize M

subject to:

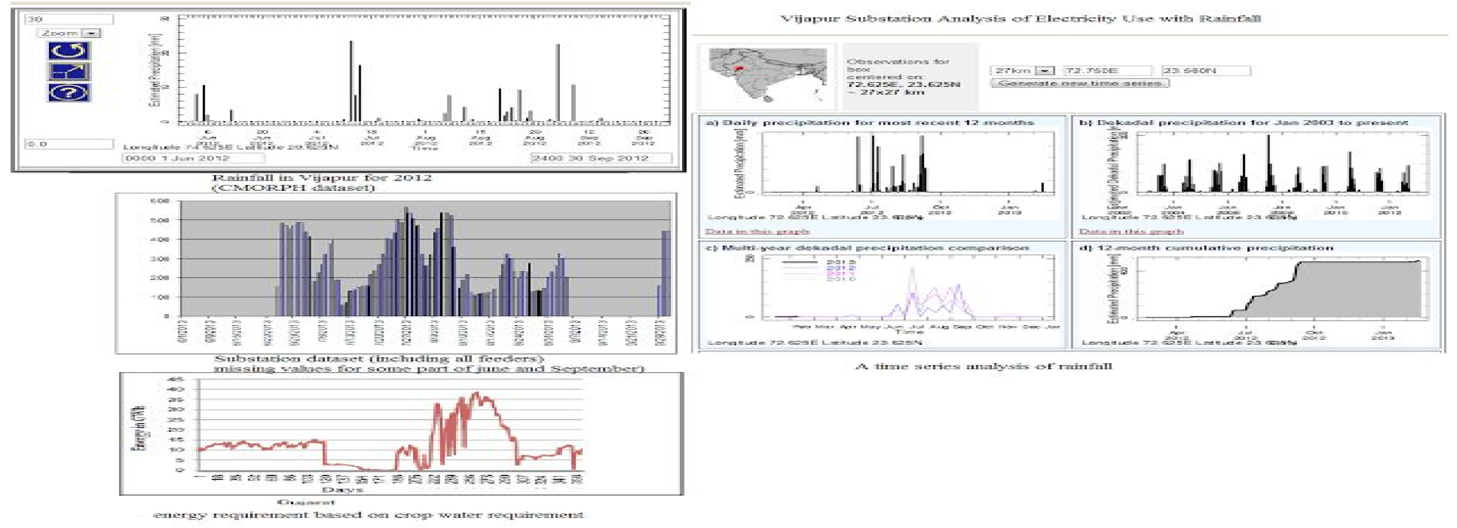
$D_t - P_t + P_{t-1} \leq S_t{*}M \quad \forall t: t>1$ (1)

$D_1 - P_1 \leq S_1{*}M$ (2)

$D_{365} + P_{365} \leq S_{365}{*}M$ (3)

Postponing of the demand is allowed given the constraints (1-3) which balance the consumed and generated energy each day and guarantee that the amount of energy requirement that is postponed to tomorrow can not exceed the demand today. Result of the model is **3.32 MW.**

4. SUMMARY



✓The image shows the climatology and the energy demand maps of the village in North Gujarat, India. The model developed can be used for analysis both on historical as well as predictive mode. Integrating short term and long term predictors can help utility plan the purchase of electricity for the future and thereby help better integration of renewable into the present energy mix.

✓Solar generation is most efficient if consumed in situ of production. Integrating Climate and Agriculture Services would mean efficient use of energy to boost the GDP of the village.

✓DSM techniques would further bring in efficiency in the system by reducing losses and the need for fresh investments in large scale power projects, as energy saved is more than energy generated.

Acknowledgements:

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