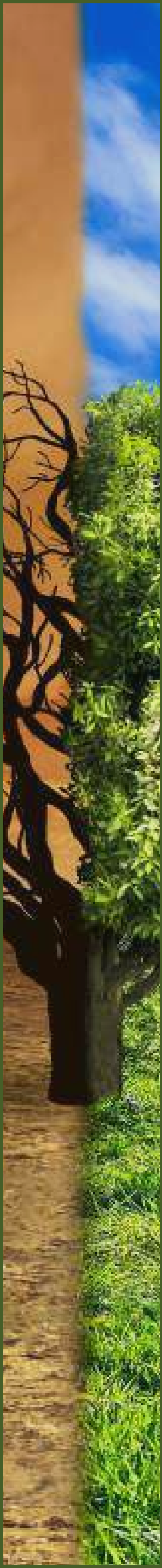


PROCINORTE

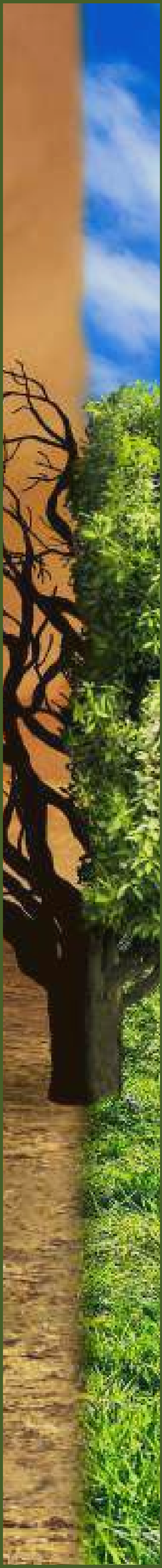
Soil, Water & Climate Change Task Force

2024 NORTH AMERICAN WORKSHOP

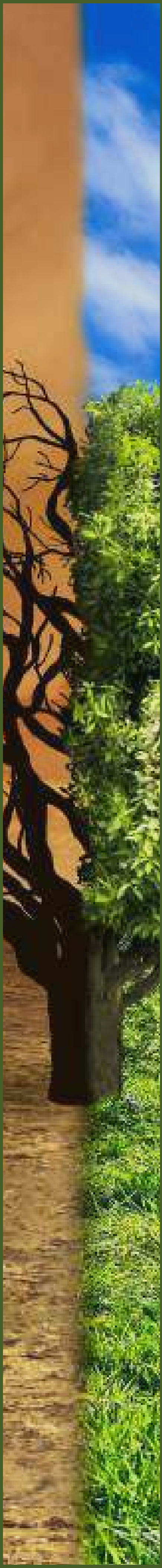
ON

SOIL, WATER, AND CLIMATE CHANGE: CAN MODELS GUIDE OUR WAY?

March 14th, 2024



ABSTRACTS



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CARBON THEME

INIFAP

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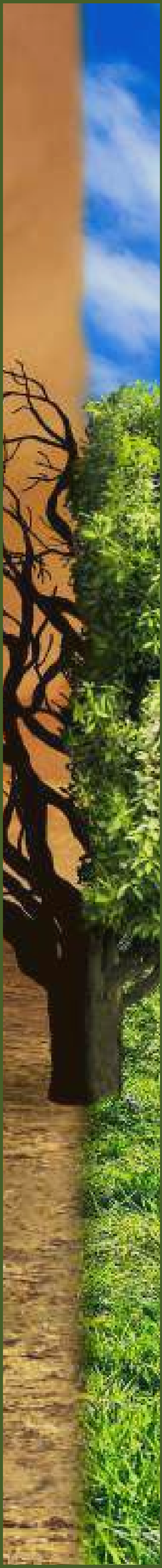

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WATER THEME

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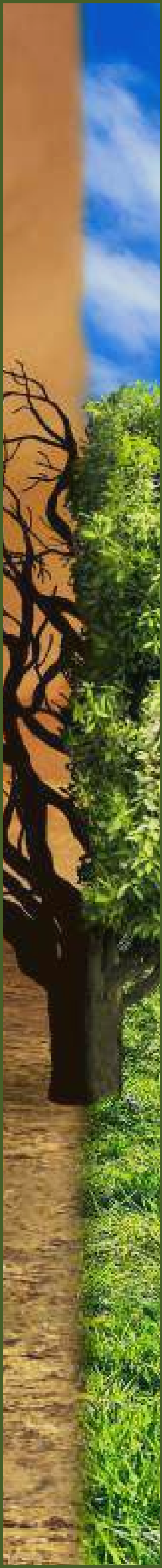

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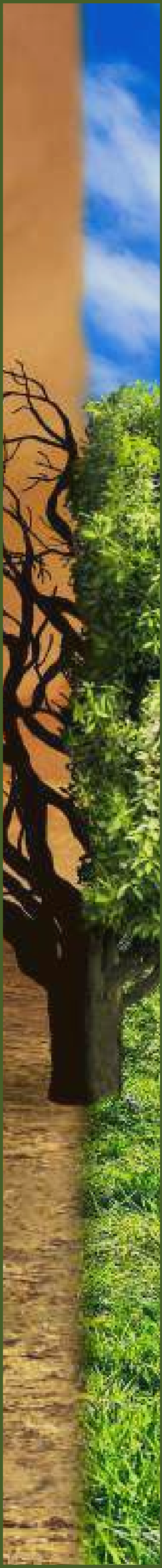

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Soil Quality Indexes as a Tool for Restoration Practices Monitoring in Mexican Croplands

INTRODUCTION

Soil degradation occurs for many reasons, from erosion to pollution, which can arise from natural processes or anthropogenic activities, which generates a decrease in soil productivity and affects the natural balance of the entire ecosystem. The restoration of the quality of degraded soils is based on increasing the storage of soil organic carbon (SOC), a key component of several soil functions that requires regular inputs of C from biomass and essential elements such as N, P, K, and S through three strategies: minimizing losses from the pedosphere, creating a positive C balance in the soil while improving biodiversity, and strengthening the water and element cycles. It is worth mentioning that the specific biophysical, social, economic and cultural factors of each site determine the best strategy to follow.

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APPROACH

The slow response of the ecosystem to restoration practices is the main cause for the desertion of producers, so the establishment of comprehensive monitoring programs of their impact on vegetation and soil quality since the short-term is a key factor to the continuity and expansion of the management.

The SOC store is the main indicator of soil quality due to its restoration, although the effect can be noticed in the medium and long-term. Other early indicators of soil quality, such as microbial diversity and activity, have a faster respond. The generation of soil quality indices and simulation models are other integral tools for the evaluation of ecosystem processes.

Therefore, the efficiency of different management practices for the restoration of degraded soils in Mexico has been evaluated through several soil indicators which aimed to establishing quality indexes that integrates quickly physicochemical and biological indicators of soil to evaluate the level of degradation/restoration since the short-term (Figure 1).

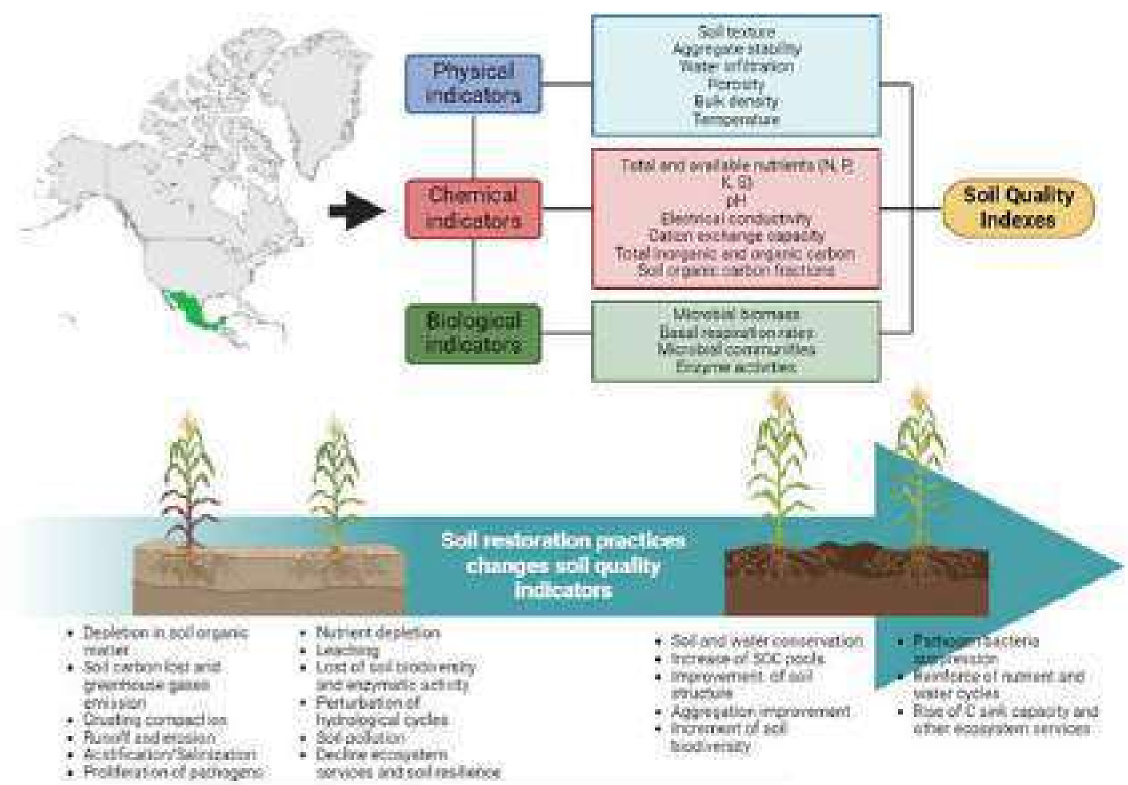

Figure 1. Soil quality indexes are key tools for evaluating the efficiency of ecosystem restoration practices.

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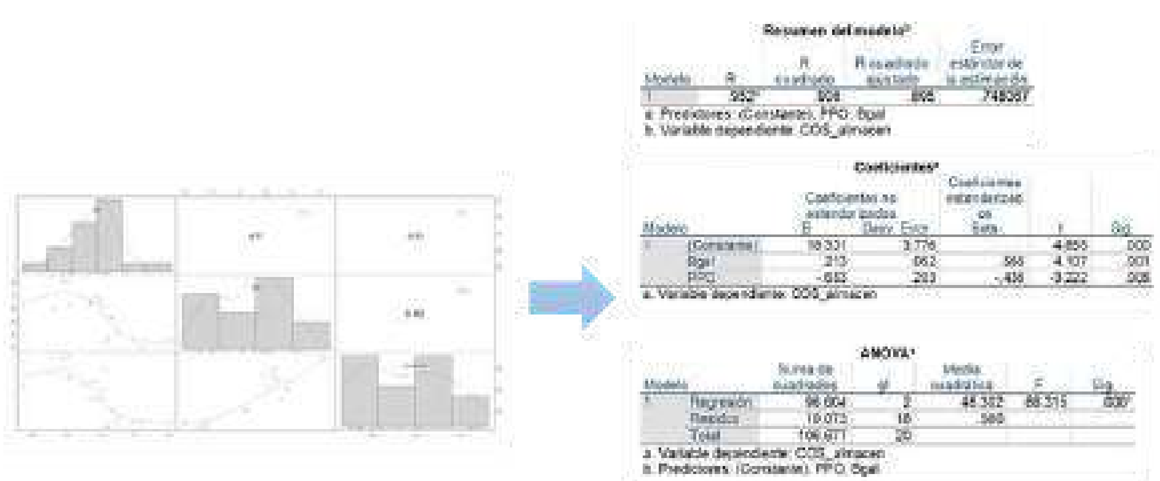
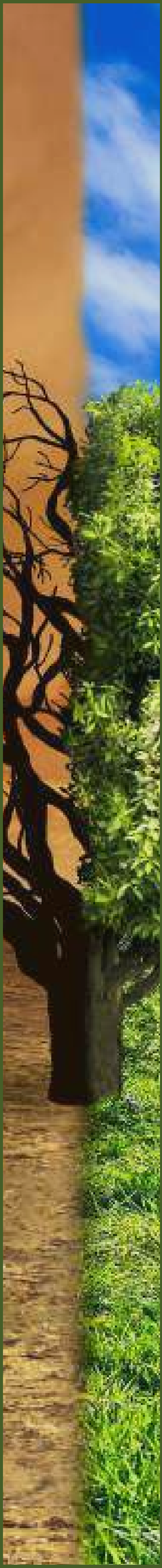
Management practices such as biofertilizer application, conservation tillage, and amendments incorporation (Cabrera-Rodriguez et al., 2020a; 2020b; Nava-Reyna et al., 2017; Vasquez-Arroyo et al., 2023) have been evaluated to determinate alteration in soil properties to indicate an increase or decrease of soil quality. Biological indicators seem to be the most appropriated characteristics to monitor soil quality since short time, due to the key role of microorganisms in soil health and fertility, by their participation in organic matter decomposition, elements biogeochemical cycles, their contribution to soil structure formation, their functions to promote plant growth and their regulation of greenhouse gases emission and mitigation (Rao et al, 2019). In this way, monitoring of soil health through changes in the population of specific microbial taxa, microbial biomass, genes, secondary metabolites, and soil enzyme activity (Djemiel et al., 2022; Lee et al., 2020). Moreover, according to the analysis of Rao (2013), SOC and labile C, soil respiration, diazotroph population, glomalin content, and enzymatic activities such as dehydrogenase, glucosidases, and acid phosphatase are interrelated and give an overview good for soil health. For example, implementing conservation practices in the Altiplano Potosino allowed a greater store of SOC, in the long and short-term, which can be largely explained by the β-galactosidase and polyphenol oxidase activities (Figure 2). In this way, a model was generated to predict the impact of tillage practices from an early stage, even before observing changes in other soil properties, such as the SOC store (Nava-Reyna et al., 2022).



$$SOC\ stock = 0.213(\beta\text{-}gal) - 0.653(PPO) + 18.331$$

Figure 2. Quality index generated to evaluated the efficiency of conservation practices based in enzyme activities.



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CONCLUSION

Generation of local quality indexes from main soil indicators is crucial to comprehend the ecosystem recovery and resilience by restoration practices, as well as a tool to monitoring the efficiency of management since the short time.

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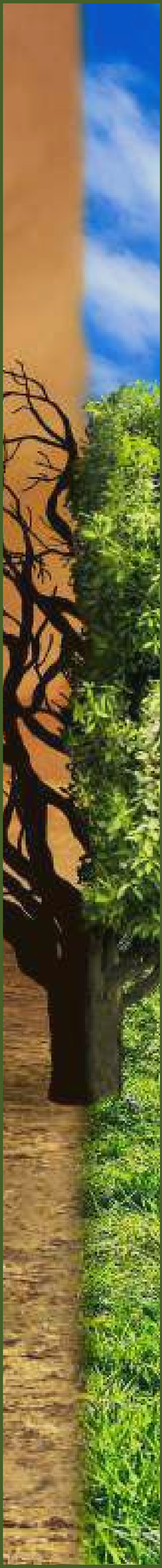

Josué Delgado Balbuena

Researcher at National Center for Disciplinary Research on Family Farming of INIFAP

Carbon Exchange, Primary Productivity and Land Use/Cover Change on Arid Ecosystems in Mexico

INTRODUCTION

Dryland ecosystems cover up to 47% of terrestrial land and store around 15% of the global soil carbon, and despite their low productivity compared to tropical and temperate humid and subhumid ecosystems, they control the interannual variability of global productivity and the tendency to increase observed productivity in terrestrial ecosystems. Land-use change (LUC) is the main human activity that controls the carbon, water and energy fluxes in the soil atmosphere continuum. International research agendas request to increase our understanding on the impact of LUC on the capacity of ecosystems to capture and store carbon to improve forecasting tools and mitigation strategies.

Grazing by domestic cattle and grassland conversions to rainfed agriculture are the main factors associated with degradation of arid lands (Velázquez et al., 2002). Grazing is an essential component of nutrient cycling and contributes to the maintenance of grasslands productivity and structure; however, when grazing exceeds the recovery capacity of grasslands, causes a disruption between soil and plant processes, promoting a decline of plant cover and leaving soils exposed to environmental factors and promoting encroachment of woody (dessert shrubs) and succulent species into the grass matrix of semiarid grasslands (Brown and Archer, 1999). In the case of land converted to rainfed agriculture, soils remain uncovered most part of the year. Under these circumstances processes such as wind and water erosion contribute to the loss of soil organic matter and CO_2 emissions, as well as enhancement soil evaporation.

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APPROACH

To know the status of ecosystems as carbon sources or sinks and their energy balance, it is necessary to carry out continuous measurements of the net exchange of CO2, water vapor and energy between the biosphere and the atmosphere. The eddy covariance method is a non-destructive micrometeorological technique that provides direct and continuous measurements of matter and energy exchange at the ecosystem level, making it ideal for measuring greenhouse gases at long-term monitoring sites (Fig. 1). The temporal and spatial scale of the data from greenhouse gas monitoring sites with micrometeorological techniques can also serve to validate various remote sensing products (e.g. MODIS), with the aim of scaling these measurements to a country scale. Mexico has a great diversity of terrestrial ecosystems that range from the dune and mangrove vegetation on the coasts, to the high jungles in the south of the Republic. This high spatial heterogeneity of ecosystems and climatic regimes imposes a great challenge for the study of biogeochemical cycles and energy fluxes. To deal with this biodiversity the National Laboratory MexFlux, which is the Mexican ecosystem-atmosphere fluxes network, brings together 13 institutions distributed in 11 states of the country, capitalizing on the effort of more than a decade dedicated to monitoring and studying the flows of energy, water and greenhouse gases of Mexican ecosystems

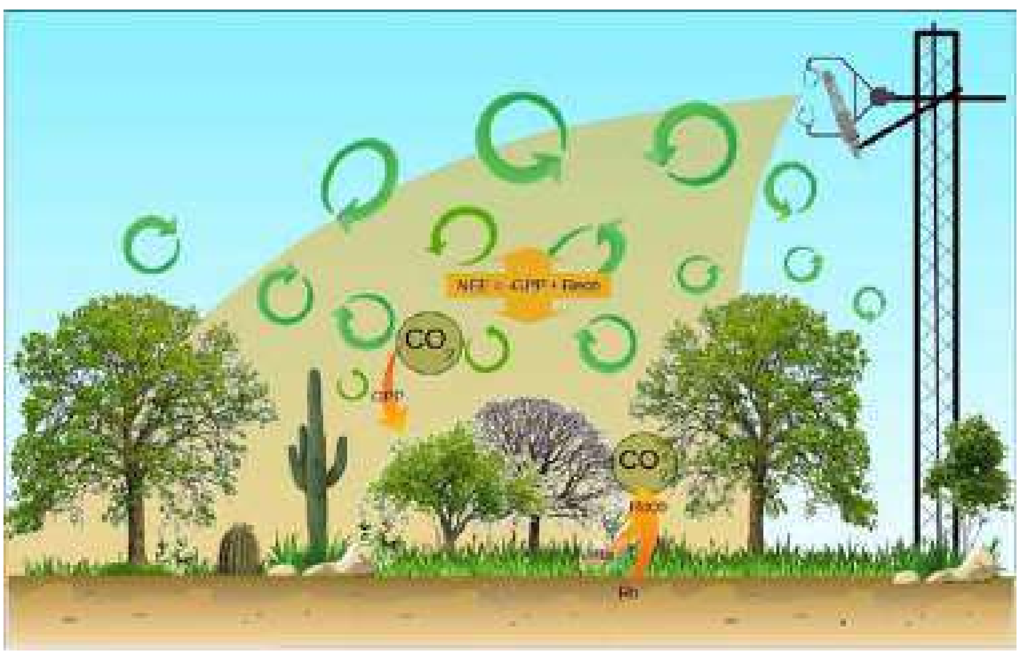

Figure 1. The eddy covariance technique for monitoring ecosystem carbon and energy exchange between biosphere and atmosphere (Delgado-Balbuena et al., 2019).

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Moreover, small and big static chambers are used for monitoring soil carbon fluxes and the net ecosystem exchange of carbon and water vapor at agricultural and natural ecosystems. These methods have the advantage of covering highly patched ecosystems but with the inconvenient of the lesser time resolution because of the effort of manual sampling (Fig. 2).

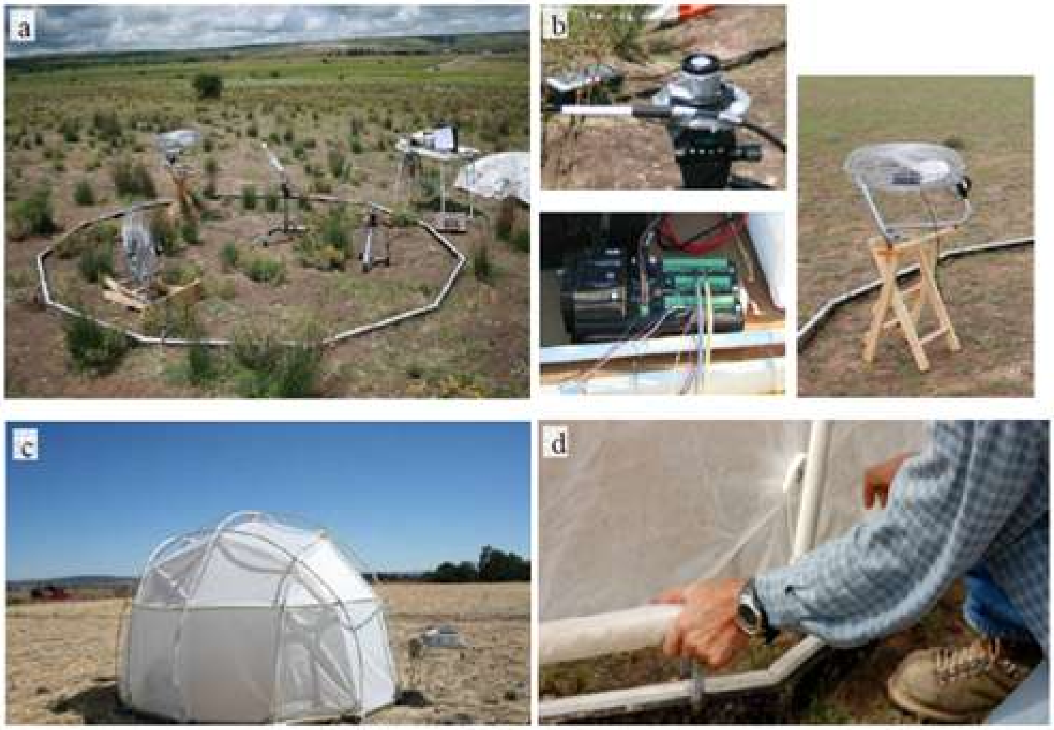

Figure 2. Dome technique. a) Sensor arrangement inside the 12-sided plot; b) ParLite, thermocouple, CR1000 and fan; c) dome on the base frame plot; d) metal base with rubber gasket and clip.

For estimating changes in cover vegetation and plant productivity at larger spatial scales, vegetation indices such as Normalized Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) from MODIS products are used to identify shrub density and invasion dynamics over time. Several spectral techniques and time series analyses are used to classify plant cover types, and to derive parameters such as the length of the growing season and the dynamics of the different phenological stages. Correlations with environmental variables and land use factors at different time scales are also used to identify drivers of changes in productivity, plant cover and tendencies of change across the arid lands of the center-north of Mexico (Fig. 3).

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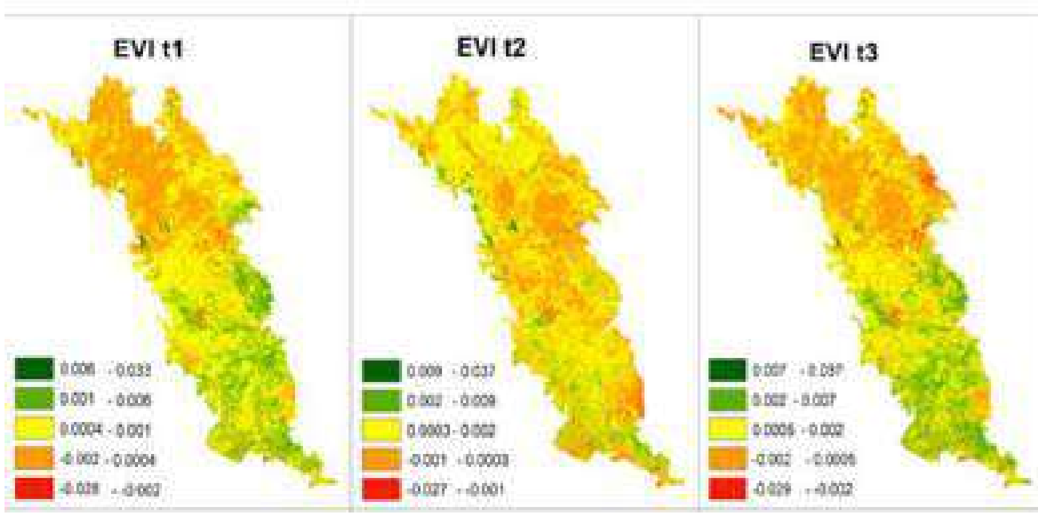

Figure 3. Spatio-temporal trends for 21 years (2000 – 2021) of the EVI in the Chihuahuan Desert.

CONCLUSION

Approximations at different scales of time and space with direct and indirect methods is crucial for understanding and dealing with complex questions. Arid ecosystems can play a much important role in the global carbon cycle; therefore, it is critical to determine through regional studies the role of grassland in the carbon balance as well as the effect of land-use change on carbon exchange.

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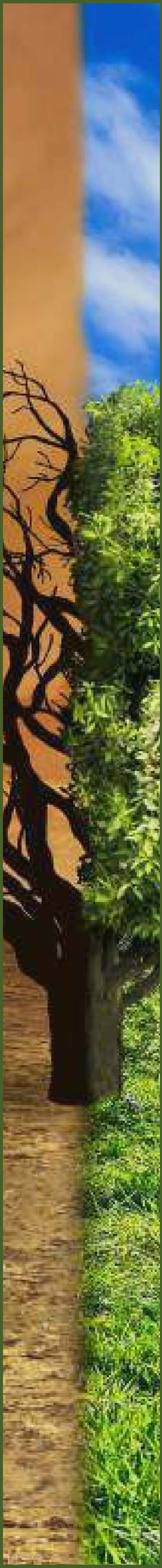

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Esteban Salvador Osuna Ceja (2)
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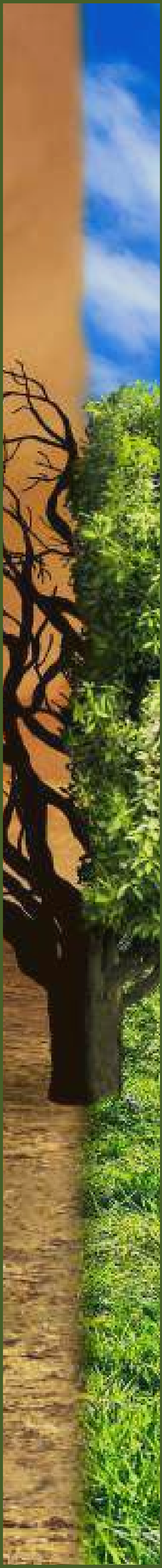
INIFAP researchers at (1) San Luis Experimental Field
(2) Pabellón Experimental Field
(3) CENID-RASPA

Conservation Agriculture. An Alternative to Regenerate Soil Fertility

INTRODUCTION

Soil degradation with inadequate methods of preparation for planting threatens more than 40% of agricultural soils and is a negative influence on the food security of a world population that by 2050 will reach 9.5 billion people (Dendooven et al. 2012). For more than 50 years, the soils of north-central Mexico have been fallowed and tracked, in addition to the total extraction of the crop residues and the practice of monoculture. The result of these actions is the destruction of soil structure and a reduction in soil organic matter content, which is reflected in a loss of soil fertility and productivity.

To reverse this physical and biological degradation of the soil, it is necessary to generate processes of regeneration and conservation of the soil structure through alternative methods in the preparation of the planting bed other than fallow and that promote the incorporation of organic matter and carbon sequestration, so that the soil improves and maintains quality parameters in terms of compaction, porosity, infiltration, fertility and productivity. Agricultural production is related to soil health, and organic matter and carbon sequestration are its main indicators, in addition to the fact that a productive soil is the best defense for producers against climatic disasters, so increasing soil organic matter and improving its structure are factors that will allow sustainable responses to food security, the effects of climate change and the reduction of greenhouse gas emissions (Verhulst et al., 2015).



Miguel Ángel Martínez Gamiño
Esteban Salvador Osuna Ceja
Erika Nava Reyna

APPROACH

Conservation agriculture is a viable alternative to improve soil structure and increase carbon sequestration. INIFAP has an experimental plot, with a corn-fodder oats rotation, at the San Luis Experimental Field, which is 28 years old. Seven treatments are being evaluated in a randomized block design with two replications. Each treatment is established in plots of 10 furrows 0.80 m apart or five beds of 1.60 m by 30.0 m long.

The treatments are: 1) fallow plus harrowing, 2) harrowing, 3) multi-tillage plus harrowing, reconverted to no-tillage + 33% cover in 2019, 4) no-tillage + 0% cover, 5) no-tillage 33% cover, 6) no-tillage + 66% cover and 7) no-tillage + 100% cover. This plot allows comparison of the cumulative effect of tillage on soil physical, chemical and biological properties.

A database is available to provide a long-term view of the effect of tillage treatments on grain and stubble yields of corn and forage oats.

There are well-defined plots where the planting area has been maintained in the same place to evaluate the accumulation of organic matter by the roots of the corn and forage oats.

Accumulation of the effect of not tilling the soil with an increase in the capture of organic matter and carbon in the soil profile of more than 4% per year.

Alternatives for the use of stubble by recommending that only 33% of the soil is left covered with stubble and the rest is used for traditional livestock feeding.

Alternatives for forage production in autumn-winter, which motivate producers to use alternative methods of soil preparation.

Quantification and identification of microorganisms in the soil that allow to know the changes in soil microbiology with methods other than the traditional fallow plus harrowing.

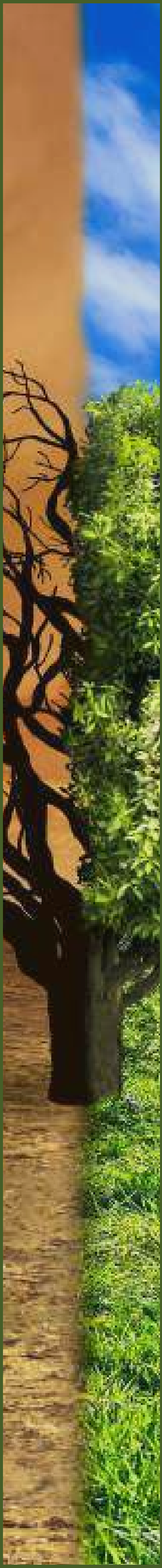
Quantification of moisture dynamics in the soil profile with permanent probes to determine the use of water in the soil profile by the crops involved in the corn-fodder oats rotation.

Quantification of soil quality parameters, such as bulk density, compaction, infiltration, moisture retention characteristic curves and porosity.

Development of functions to estimate the effect of organic matter incorporation on carbon sequestration.

Given the age of the plot, it is an excellent scenario as a school plot for training technicians and producers.

Drones are being used to determine crop parameters.



Miguel Ángel Martínez Gamiño
Esteban Salvador Osuna Ceja
Erika Nava Reyna

CONCLUSION

The experimental plot is a scenario to continue evaluating the effect of soil tillage methods to improve soil structure and a significant contribution of organic matter and carbon sequestration to increase physical and biological fertility.

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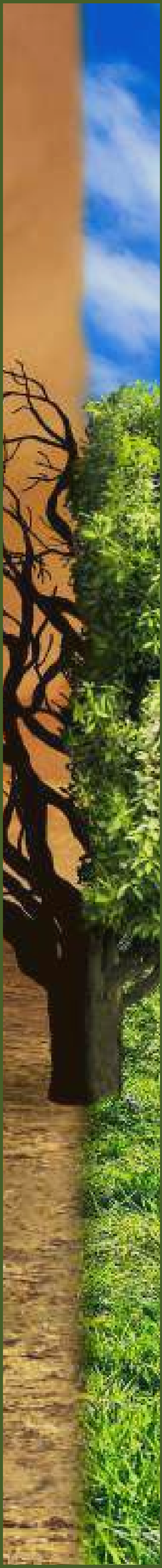

Esteban Salvador Osuna Ceja

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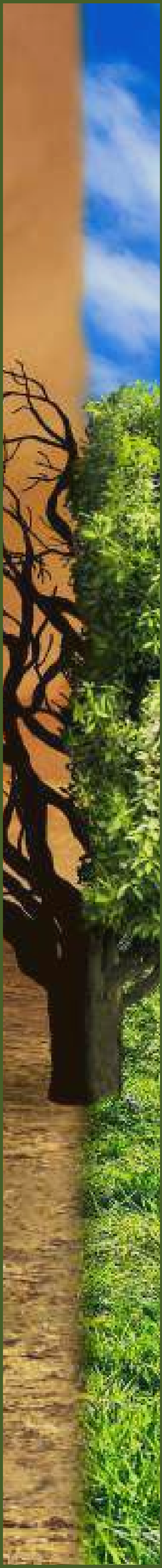
Research for Sustainable Food Production at INIFAP Development of Regenerative Agriculture

INTRODUCTION

There is growing concern in the world about the accelerated deterioration of natural resources caused by production systems, both those of high inputs and technology and those of subsistence. Both types of systems lead to the degradation of soil, water, natural vegetation and the environment in general. The situation described above is very dangerous as it is causing a decrease in available food for the growing human population, whose needs are increasing along with its growth. There is an urgent need to change food production technology in Mexico. The change has required research on the basic processes that can be used to develop a technology that can be adapted by producers, who must increase productivity and at the same time conserve natural resources. This is the objective of one of the priority lines of research of the INIFAP-CIRNOC-CIRNE-CENID-RASPA Soil Program, which seeks to generate specific knowledge and technologies for sustainable production, as well as to support their transfer.



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APPROACH

From the above, the need to carry out research on sustainable production following different paths to those currently used, managing processes, not isolated actions, emerged. In the face of new scenarios, we work in an interdisciplinary manner and with innovative aspects. The starting point was the identification of priority problems in agricultural and forestry production, defining the most important production system in which the priority problem is contained. The system is analyzed considering its main components, by following the following steps: a) identification of the system, b) dominant environmental factors, c) products and by-products, d) inputs, e) socioeconomic aspects, f) pollution and other critical factors that affect the conservation of the ecosystem.

Once the problem-system under study has been identified, the soil program proceeds to carry out research that is closely related to the specific problem to be solved. For example: The Temperate, Semi-Arid Region of North-Central Mexico suffers from the problem of land degradation that triggers interrelated processes, such as erosion, deterioration of physical, chemical and biological properties and loss of biodiversity, in the agricultural and forestry areas. This demanded comprehensive research that considered: a) Soil conservation practices (vertical tillage or conservation tillage); b) Rainwater harvesting practices in situ (contour strips, pile driving and corrugations); c) Design of agricultural implements (Integral bibiometic subsoiler, "Pileteadora", Aqueel roller, Integral seeders for sowing in beds at 4 and 6 rows); d) Management of living barriers [Use of Opuntia sp. based on three rows planted at high densities (between 1800 and 3600 plants ha-1) in staggered rows and against slope]; e) Crop rotation (planting at high densities of beans, corn and sunflowers); f) Crop rotation (planting at high densities of: beans, corn and sunflower at 4 rows [170,000 plants ha-1], canola sorghum and oats at 6 rows) and forage grass; f) organic and biological fertilization (use of dry manure [5 T ha-1] , inoculum of mycorrhizae and rhizobium) and g) Management of small livestock (Pelibuey sheep initiated in development stage 5 heads ha-1), fed with crop by-products (ration: 40% corn stubble, 10% bean straw, 45% hayed oats and 5% corn grain), water and mineral salts and direct grazing. The production system seeks to integrate agricultural, livestock and forestry components at the production unit level to contribute to the improvement and conservation of resources and increase their productivity.

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This sustainable production model is an alternative that can improve the profitability of agricultural and forestry activities, while complementing efforts to restore degraded agricultural lands in this region of the country and implement the development of Regenerative Agriculture (defined as soil rehabilitation to keep it productive for as long as possible to avoid aggressive expansion of new areas).

The methodology used to evaluate the sustainability of the developed system is based on using the MESMIS technology (Framework for the Evaluation of Natural Resources Management System Incorporating Sustainability Indicators); as well as the prediction technology through a dynamic simulation model EPIC (Environmental Policy Integrated Climate), used to evaluate the impact of erosion on the productivity of the crops that integrate the sustainable production system in the production unit.

Figure 1. Diagram of a sustainable production system using a holistic methodology.

Esteban Salvador Osuna Ceja

In accordance with the methodology proposed by MESMIS, a sustainability evaluation was carried out based on the comparison of the traditional system (reference system) with the innovative system. In this exercise, a comprehensive technical-environmental, economic and social evaluation of both systems was carried out. The comparison of the two systems was carried out through a series of qualitative and quantitative indicators, which allows a graphic representation of the results that highlight the strengths and weaknesses for crop production and soil and water conservation (Figure 2).

As an example, Figures 3 A, B and C show erosion, runoff and yield data simulated with the EPIC model, for rainfed bean cultivation, under the two technological modalities, traditional and sustainable, for a period of 50 years.

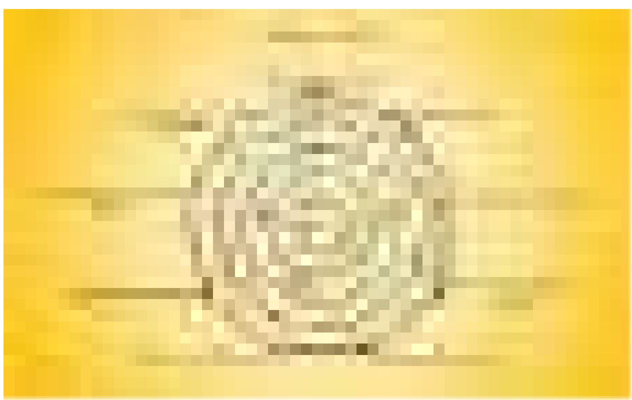

Fig.2. MESMIS Methodology

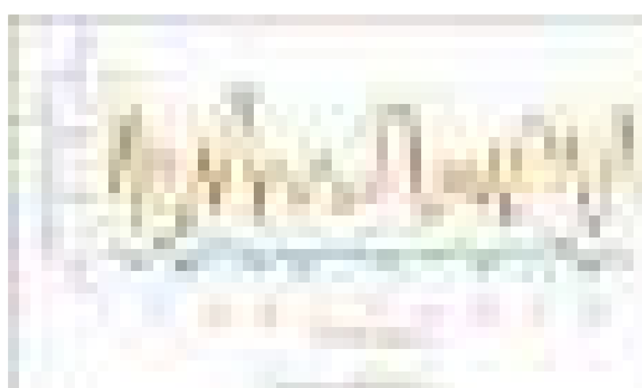

Fig.3. EPIC Model

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CONCLUSION

The rural development model to be followed should be one of a local nature in which the principles of sustainability are adopted. This model should include the paradigms of regenerative agriculture in all the agricultural, livestock and forestry components of the territory. The yield increases obtained in the ten years of work show that the technological modifications are yielding results in productive terms and the increase in soil organic matter and the recovery of biodiversity in the work areas indicate the sustainability of the actions carried out.

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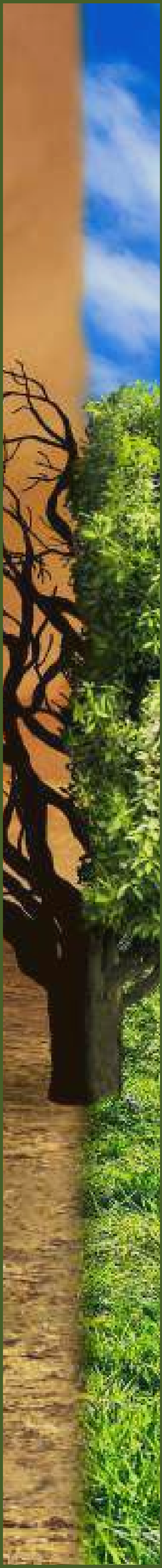


USDA

Hero T. Gollany

Researcher at USDA – AR – Columbia Plateau Conservation Research Center (CPCRC), Pendleton, OR

Field Scale Soil Organic Carbon Modeling Using Long-Term Agricultural Experiments and the Process-Based CQESTER Model

INTRODUCTION

Soil carbon (C) models are useful tool for examining the complex interactions between climate, crop, soil properties, and soil management practices and their influences on long-term changes in soil organic carbon (SOC). The C model 'CQESTR', pronounced 'sequester,' was developed by USDA-ARS scientists at the Columbia Plateau Conservation Research Center, Pendleton, Oregon, USA. The CQESTR model was developed to evaluate the effect of agricultural management practices on short- and long-term SOC dynamics. The CQESTR model (v. 2.0) is a process-based soil C balance model that computes the rate of biological decomposition of crop residue or organic amendments as they convert to soil organic matter (SOM) or SOC up to 5 layers or depths. The model is used for the field scale evaluation of SOC stocks (Liang et al., 2008; Rickman et al., 2002). The model operates on a daily time-step and performs long-term (100-yr) simulations. The C pools are depicted as a continuum. The basic model structure and C flow in the CQESTR model is illustrated in Fig. 1.

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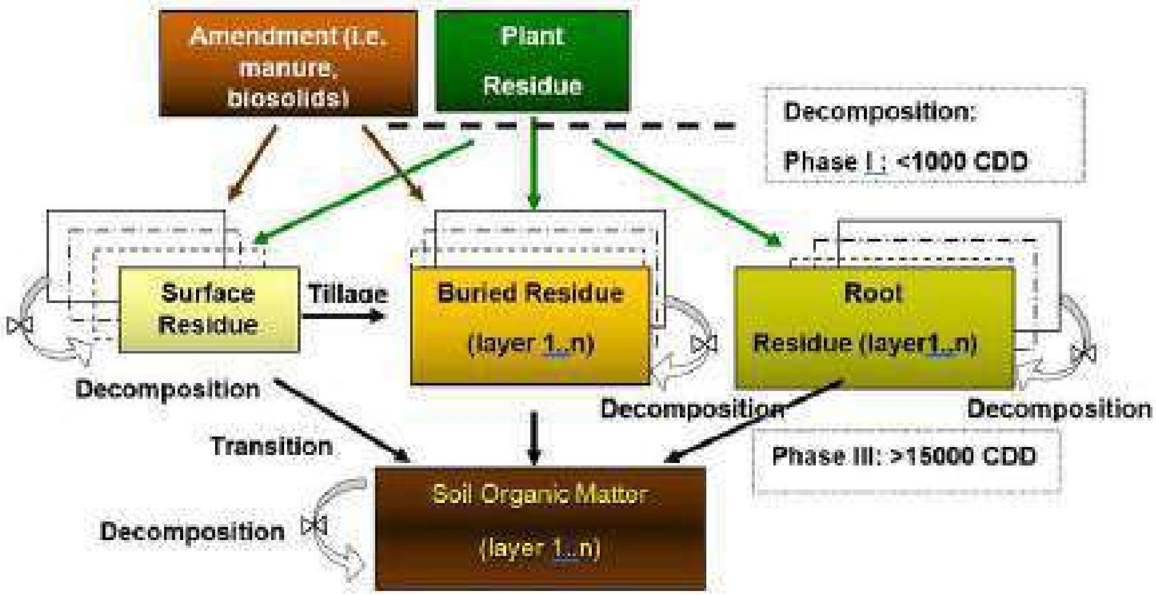
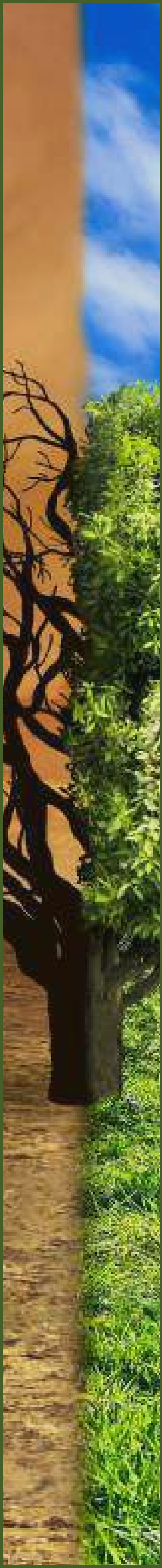


Fig.1. Schematic of carbon flow in the CQESTR model. Ecological Modelling. 220(4): 568-581.

Organic material decomposition is a three-phase process. After each residue placement in the soil, decomposition occurs in two phases. Phase I is a rapid phase covering the first 1000 cumulative degree-days (CDD, thermal time), approximating the oxidation of readily metabolizable substrate. Phase II is a slow decomposition phase, representing oxidization of more recalcitrant materials. Crop residues and organic amendments are categorized by their placement in the soil and their identities are maintained during the two-phase decomposition. Each organic residue addition is tracked separately according to its placement within distinct soil horizons. After 15,000 CDD when Phase II is complete, the composted residue is transferred to the stable SOM pool (Phase III).

INPUTS

The CQESTR model uses readily available input data at the field scale. Data inputs include weather, above-ground and below-ground biomass additions, N content of residues and amendments, soil properties, and management factors such as tillage, crop rotation, crop grain yields, shoot-to-grain ratios, dates of all operations (e.g., tillage, seeding, harvest, biomass addition, biomass removal, etc.), depth of tillage and the fraction of the soil surface covered, and effects of tillage on residue (e.g. fraction of pre-tillage residue weight remaining on the soil surface after each tillage).



Hero T. Gollany

CALIBRATION AND VALIDATION

The model was calibrated using information from 6 long-term experiments across North America (Breton, AB, 60 yrs.; Columbia, MO, >100 yrs.; Florence, SC, 19 yrs.; Hoytville, OH, 31 yrs.; Lincoln, NE, 26 yrs.; and Pendleton, OR, 76 yrs.) having a range of soil properties and climate. The CQESTR model was validated using data from several additional long-term experiments (8 – 106 yrs.) across North America having a range of SOM (4.2 – 33.6 g SOC/kg).

Fig.2. Capivara Farm site management history, state of Goias, Brazil.

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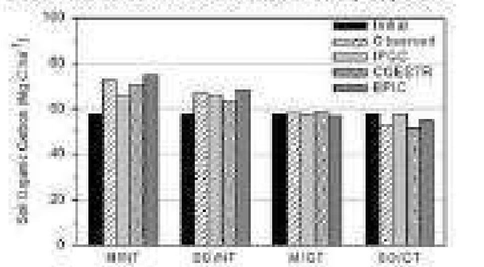
Fig.3. Comparison of the observed SOC with CQESTR, IPCC, and EPIC simulated SOC for maize and soybean under conventional and no-till at Lincoln, NE, USA.



CONCLUSION

The CQESTR could be used as support tool for decisions making to predict changes in SOC after deforestation in tropical savannah or changes in management from raw cropping systems to integrated crop-livestock cropping system, or to examine agricultural management practices, and to predict impacts of climate change on SOC under diverse agricultural management practice to generate strategies for improving adaptation/mitigation in the agriculture sector.

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John M. Baker
Timothy J. Griffis

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The Tall Towers Network: Tracking Agricultural GHG Emissions at Continental Scale

We envision that the optimal strategy for demonstrably reducing agricultural GHG emissions requires a 3-pronged approach:

1. Testing of proposed management practices – paired measurements of emissions from current and proposed practices, at the lab, plot, and field scale.
2. Scaling up - Incorporation of knowledge learned from plot and field-scale research into models, to estimate possible impacts of wide-scale adoption of improved practices on overall emissions.
3. Verification – Regional-scale emission measurements, to evaluate the performance of the model(s) used to scale up, to identify missing or underrepresented sources, guide further management practice research, and track overall progress toward emission goals.

Tall tower measurements provide the means to verify and improve models and inventories, and to identify previously unknown sources, hot spots, and hot moments (episodic emissions) within a relatively large source region (~ 10,000 km2), using continuous high-precision concentration measurements of air drawn from the top of the tower, following published methods from the trace gas observatory at the KCMP radio tower in Rosemount MN (see references).

John M. Baker
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We are establishing a network of 6 such tall-tower trace gas observatories strategically placed to broadly cover areas of the US where application of N fertilizer and biological N fixation are most concentrated, in order to:

- provide the top-down data that are necessary for testing bottom-up estimates and process-based modeling of agricultural GHG exchange (CO2,, N2O, and CH4)
- identify regional hot spots of concern for N2O and CH4 emissions
- guide formation of effective mitigation strategies at local to national scales
- provide a benchmark for tracking our progress in reducing agricultural GHG emissions

The rationale for focusing initially on the Corn Belt is evident in national maps of the distribution of agricultural N (see figs below), and while agricultural CH4 sources are more broadly distributed, a substantial amount of the total is generated in this same region.

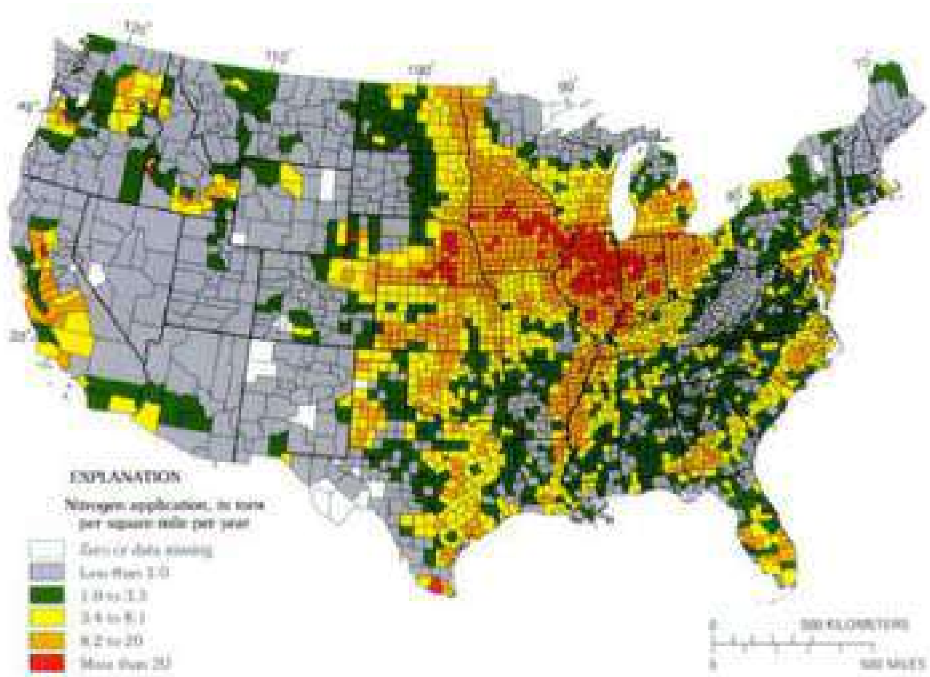
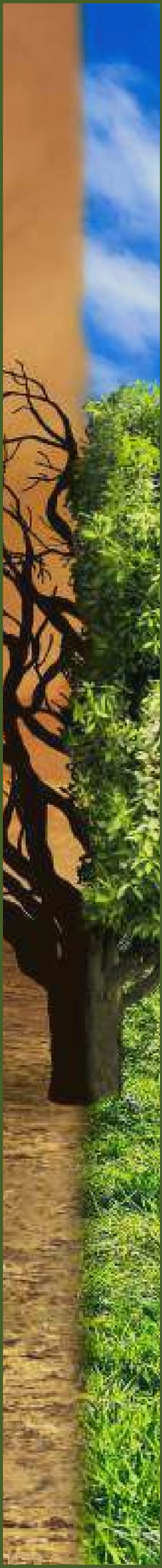


Figure 1. Annual application of fertilizer N. (source:SERC, Carleton College, Northfield MN).



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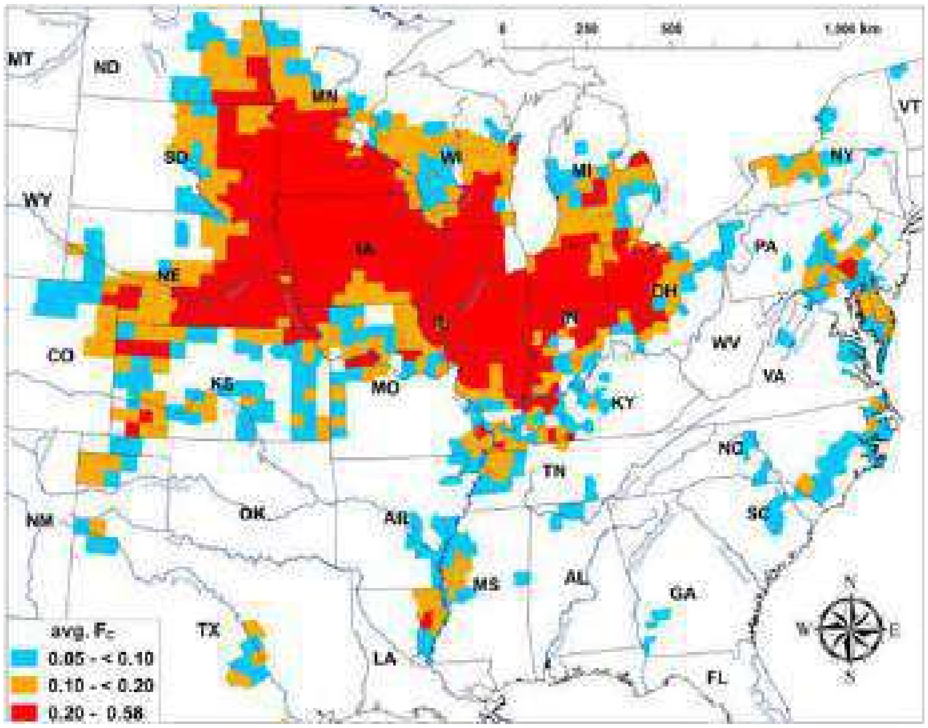

Figure 2. Map of corn cropping intensity, defined as the ratio of corn cropland area to total county area. (from Green TR, et al. 2018).

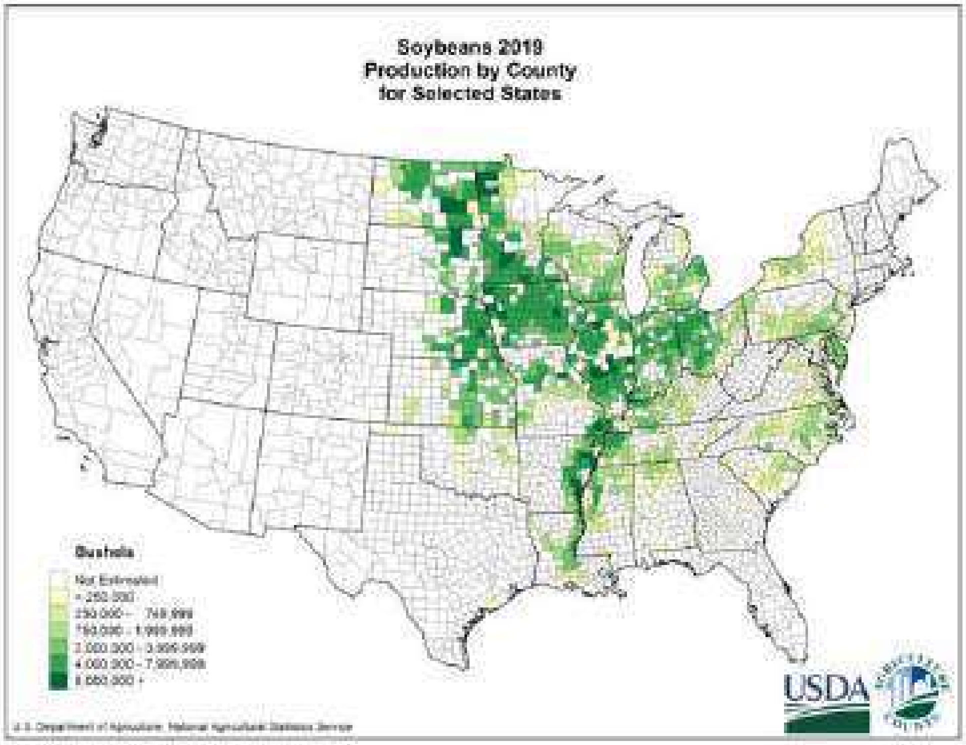

Figure 3. Distribution of soybean production as an estimator of the distribution of biological N fixation in US agriculture. Soybean is the most widely planted legume, with more than 5 times the acreage of alfalfa, the second most common legume.

John M. Baker
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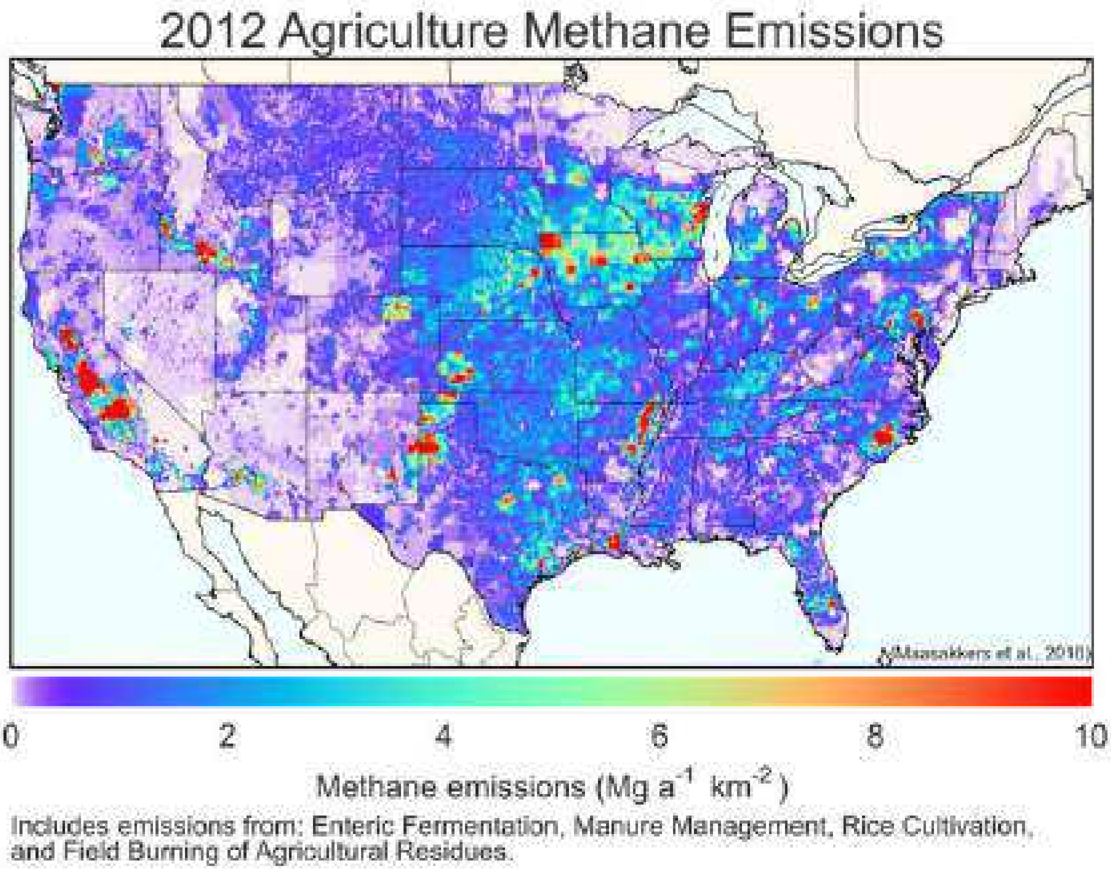
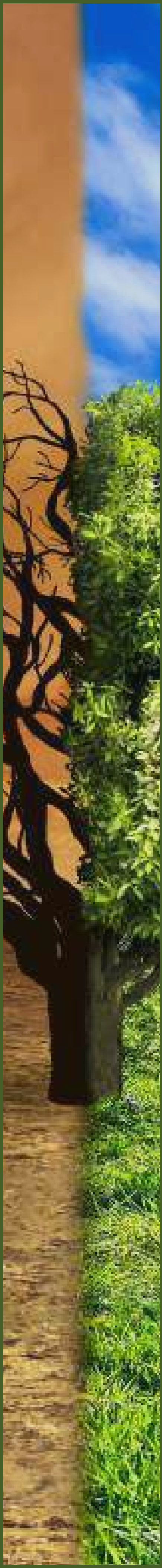


Figure 4. Methane emission distribution across the conterminous United States, 2012. Source: EPA (EPA, 2021.



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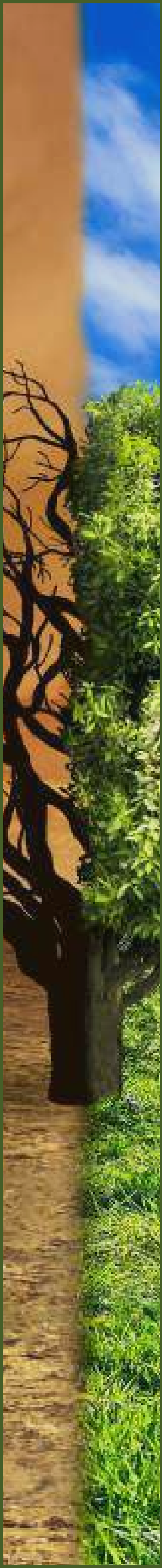


Russell L. Scott

Researcher at Southwest Watershed Research Center, United States Department of Agriculture, Agricultural Research Service

Ecosystem Water and Carbon Cycling in Dryland Regions

Dryland flux datasets enable novel quantification and modeling of water availability and carbon exchange in Southwest United States and northwest Mexico

INTRODUCTION

The climate is getting drier and hotter throughout many of Earth's dryland regions. With these changes, dryland ecosystems are experiencing more extreme climatic conditions, and over the last two to three decades, we have seen long-term drought conditions as well as a greater frequency of weather extremes in the drylands of southwestern United States and northwestern Mexico ("Southwest"). However, we lack understanding of how these climate shifts impact the water cycle and the carbon sink functioning in dryland ecosystems that play a globally important role in modulating the trend and variability of the terrestrial carbon sink.

Russell L. Scott

APPROACH

In this presentation, we will show what long-term measurements of land-atmosphere carbon and water fluxes reveal, in never-before seen detail, about semiarid ecosystem responses to, possibly, this new climate regime of the Southwest. To do this, we collated eddy covariance data from 25 sites (Fig. 1) in the water-limited Southwest region of North America with observed ranges in annual precipitation of 100–1000 mm, annual temperatures of 2–25°C, and records of 3–10 years (150 site-years in total). Eddy covariance measurements quantify ecosystem-scale fluxes of water and carbon dioxide every 30 minutes. From these, annual fluxes were integrated using site-specific ecohydrologic years to group precipitation with resulting ecosystem exchanges.

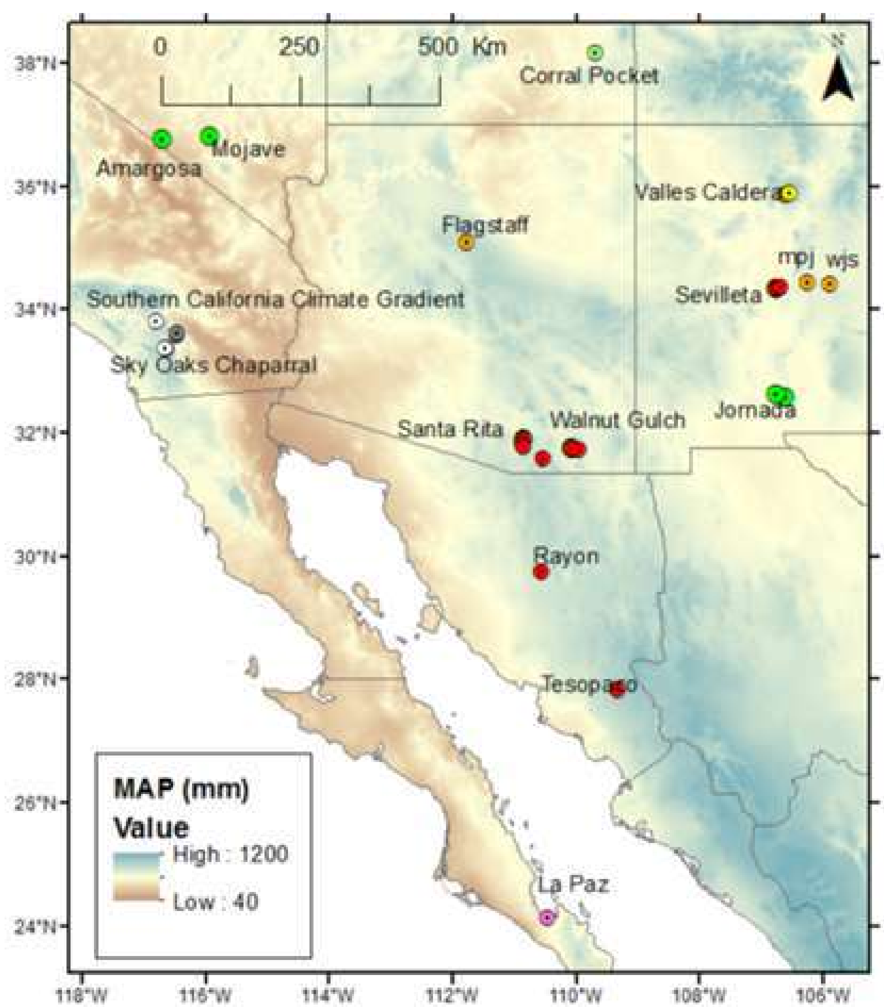


Figure 1.Location of the eddy covariance sites in the Southwest and mean annual precipitation across this region (from Biederman et al. 2017).

Russell L. Scott

APPROACH

In Using this dataset, we will first look at how Southwestern ecosystems respond to variability in precipitation both temporally at a site and spatially across the region. We also examine how well state-of-the-art remote sensing and land surface models capture the temporal and spatial variability of the annual evapotranspiration and carbon dioxide fluxes (Figure 2).

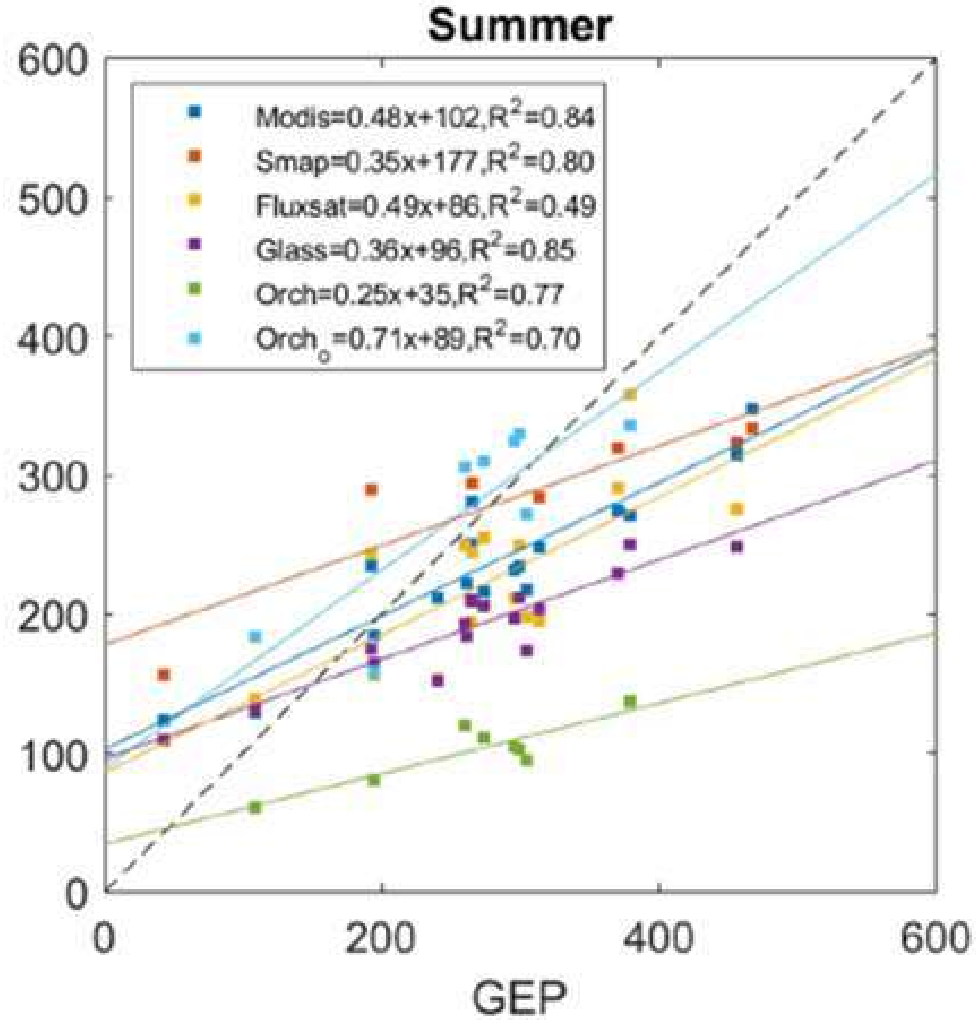
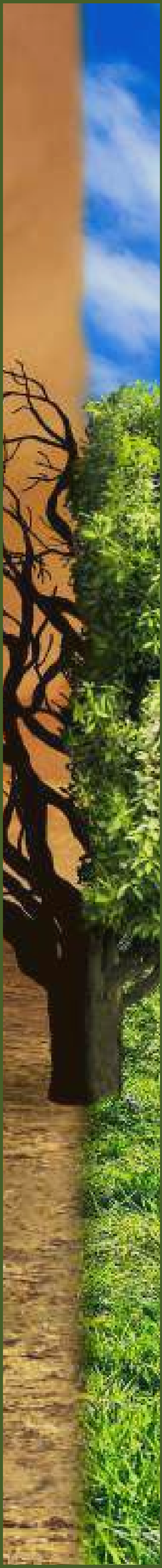


Figure 2. Example of measured vs. modeled summer growing season gross ecosystem productivity (GEP, gC m-2) totals for the Santa Rita Mesquite Savanna site (from Scott et al. 2023).



Russell L. Scott

CONCLUSION

Understanding ecosystem functional response to climate forcing at multiple time scales is critical for the improvement of earth-monitoring satellite algorithms and land surface models needed for improved land management.

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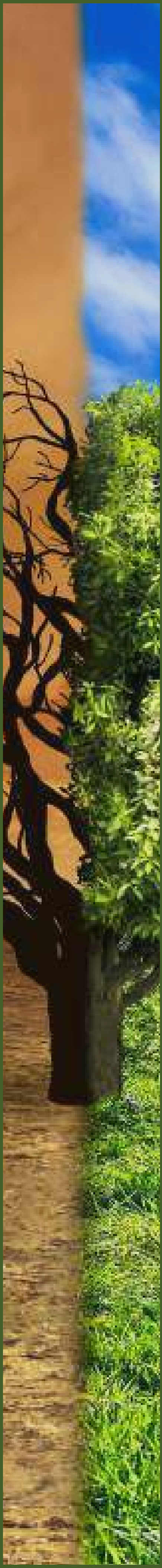

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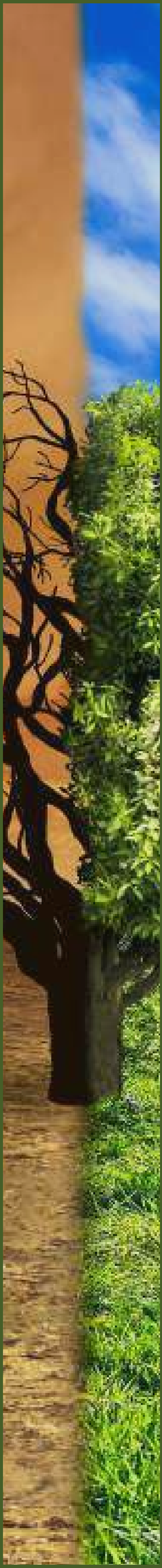

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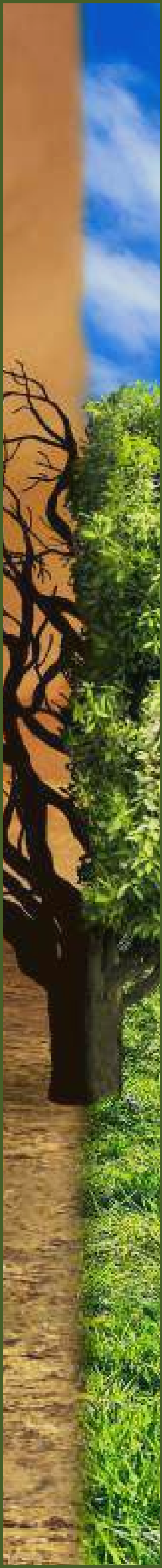
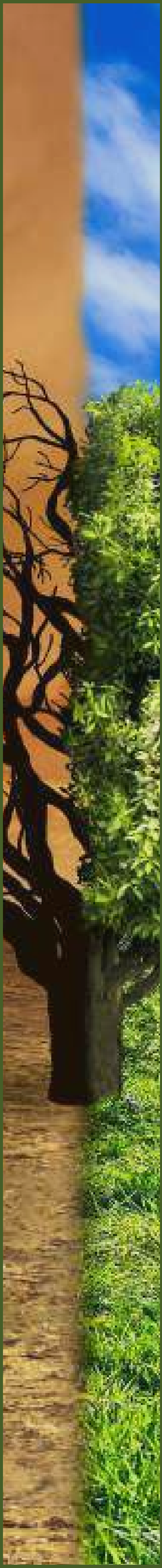
Management Practices to Enhance Soil Carbon Sequestration in Canadian Agroecosystems

ABSTRACT

Enhancing carbon (C) sequestration is one of the strategies to help Canada achieve its greenhouse gas (GHG) emissions reduction targets. Canada has large and diverse landscapes, agroecosystems, soil types, and cropping systems. The Canadian Government aims to reduce GHG emissions by 40% below the 2005 levels by 2030 and reach net zero by 2050. In this presentation, researchers from Western and Eastern Canada will define the status quo of soil C, cropping systems, and grassland ecosystems in their respective agro-ecozones, the current biggest challenges as well as past and/or ongoing management practices to enhance soil C sequestration and stability. We will also highlight research gaps and potential areas of collaboration.



Water Theme



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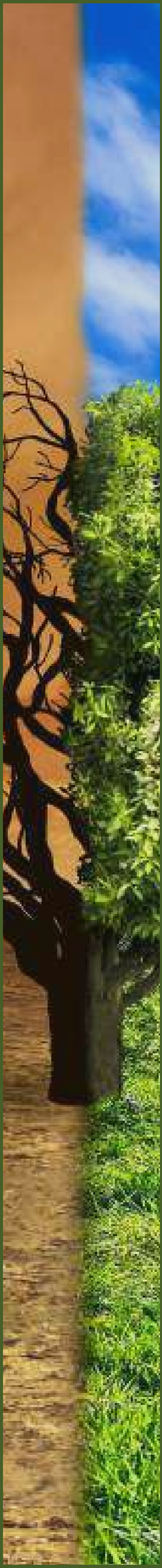

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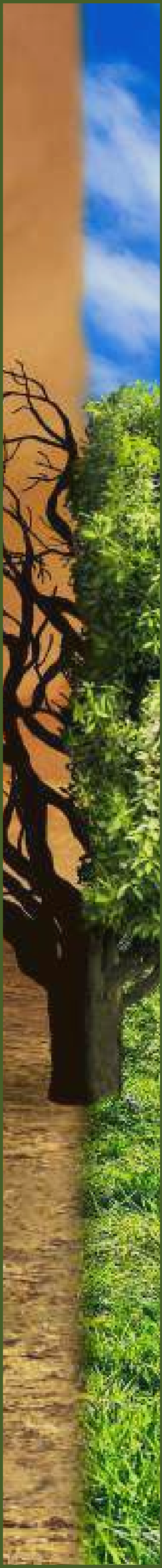
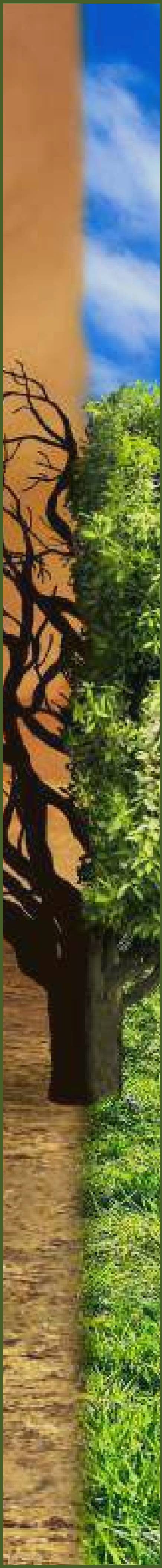
Balancing water resources sustainability in the face of Canadian climate extremes

ABSTRACT

Canada is a water-rich country. It has only 0.5% of the world's population, but its landmass contains approximately 7% of the world's renewable freshwater supply. The agricultural sector is by far the biggest user of freshwater, accounting for 67% of the world's total freshwater withdraw, and 86% of its consumption. Agriculture is in a polarizing position highly dependent on water resources, while also increasingly subject to water risks in terms of quantity and quality. Agricultural regions globally have been subject to extensive and increasing water constraints. Climate change is projected to increase the fluctuations in precipitation and surface water supplies, reducing snow packs and glaciers, causing major droughts and flooding events, diminishing surface water and groundwater water reserves, and affecting crop water requirements. Coupled with these changes, producers in many regions will face increasing competition from non-agricultural users due to rising urban population density and water demands from the energy and industry sectors. Improving agriculture's water resources is therefore essential to a sustainable and productive agro-food sector. In this presentation, researchers from Canada will define the status quo of water resources in Canada, the current challenges as well as past and/or ongoing management practices to enhance the quantity and quality of water. A theme of 4M water stewardship will be proposed involving, measuring, managing, modeling and mapping water. The science discussed will enhance the agriculture sector's resiliency to increasing hydrological and climatic variability. Exploration into potential areas of collaboration and developing new opportunities for the agricultural sector to improve water quality and reduce water quantity issues for all stakeholders will be the focus.



INIFAP



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Rafael A. Guajardo Panes (1)
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Senior Researcher at INIFAP in the (1) Climate Vulnerability and (2) Watershed Management program

Spatial Modeling of the Productive Potential of Socioeconomically Important Species in Mexico

INTRODUCTION

Undoubtedly, two of the key words to promote the sustainable development of the Mexican countryside are what and where to plant. With the advent of geographic information systems (GIS), these two questions can be answered in a practical and efficient manner. In this sense, the term "productive potential" was coined in Mexico in the 1990s, defined as the geographic-spatial delimitation of the areas or zones where it is feasible to produce different agricultural, livestock or forestry species with greater probability of success, with little or no damage to the environment.

METHODOLOGY

To study the productive potential of a species, two processes are basically required: a) to clearly and precisely define the agroecological requirements of the crop (RAC), and b) to contrast these with the conditions offered by the environment in the geographical space.
An important tool for defining the ecological requirements of crops is FAO's ECOCROP global database (2011), which contains the CARs of approximately 1,700 crops of economic and social importance. This information can be complemented with that available in Ruiz-Corral et al. (2013) and Díaz-

Gabriel Díaz Padilla
Rafael A. Guajardo Panes
Ignacio Sánchez Cohen

Padilla et al. (2012), or by interviewing leading producers in a crop of interest. With this information, we formed what we call the agroecological requirements curve, which graphically specifies the RACs that will be used later in the GIS to obtain the maps of productive potential.

Once the RACs are defined, we proceed to their integration and analysis by map algebra, to find the areas with high, medium and not suitable productive potential, the process to achieve this objective is shown in Figure 1

Figure 1. Algebra of maps to obtain the productive potential.

RESULTS

The final product of the process are digital maps where the productive potential zones are geographically delimited and classified into three categories: high, medium and not suitable (Figure 2). For each of the crops, state and municipal areas are estimated for each of the classifications.

Gabriel Díaz Padilla
Rafael A. Guajardo Panes
Ignacio Sánchez Cohen

CONCLUSION

Currently, an algorithm capable of generating specific cartographic material for any required crop is available. So far, the delimitation of the productive potential of 55 crops considered of socioeconomic importance in Mexico has been completed. This progress is crucial for the implementation of measures aimed at productive reconversion and adaptability in agricultural areas of the country that are particularly vulnerable to climate variability conditions induced by climate change.

LITERATURE

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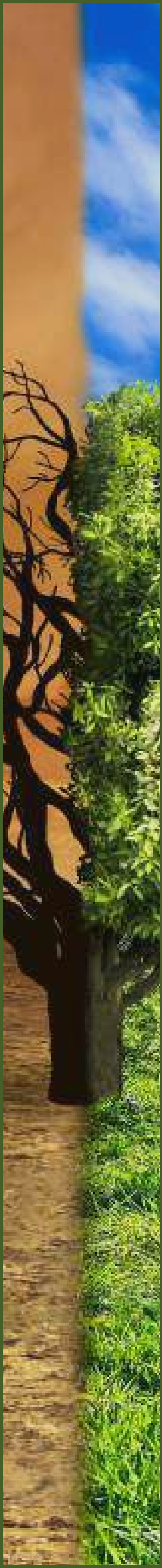

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Researchers at the National Center for Research on Water Soil Plant and Atmosphere relationships of INIFAP

Research on Watershed Modeling in INIFAP: Developing a Decision Support Platform

INTRODUCTION

The high variability in space and time of water availability, makes difficult the proper planning and sustainability of this natural resource. The situation requires of analytical approaches for decision support based on the obtaining, analysis, and synthesis of information from different sources. Considering the watershed as the basic unit for water balance and use within the country, it is convenient that the courses of action consider that scale for facing the challenges that the changes in climate patterns imposes. In Mexico, there exist information concerning water availabilities and uses at different scales and platforms. In addition, there are URL domains with spatial information, useful at certain level of decision taking. Nevertheless, these platforms do not consider implicit algorithms that allows the user climatic-hydrological analysis with the objective of pinpoint watershed decisions with impact within the ecosystems.

Ignacio Sánchez Cohen
et al

APPROACH

From this, it is obvious the need of huge volumes of information from different sources to structure robust data bases useful in the process of decision taking. The analytical scheme “BIG DATA” allows data acquisition (structured or not) for informed decision taking. This information may converge in a global database (knowledge base) as consultation through a digital platform that facilitates the process.

A digital platform with user-friendly interfaces is being developed for the synthesis, analysis and deployment of water-resources information within the 37 hydrological regions of Mexico. Information resides in several servers as well as in the INIFAP CENID RASPA server as source for the many computer applications that the computational APP it involves, (Figure 1). The APP is developed in a PYTHON environment and the back end is an executable file rather that a web site.

Table 1 shows the capabilities of the application so far. One of the main characteristics of the APP is that the user may use simulation models for quantifying decision variables as runoff or soil erosion as well as soil water balance in irrigation and / or rain feed agriculture.

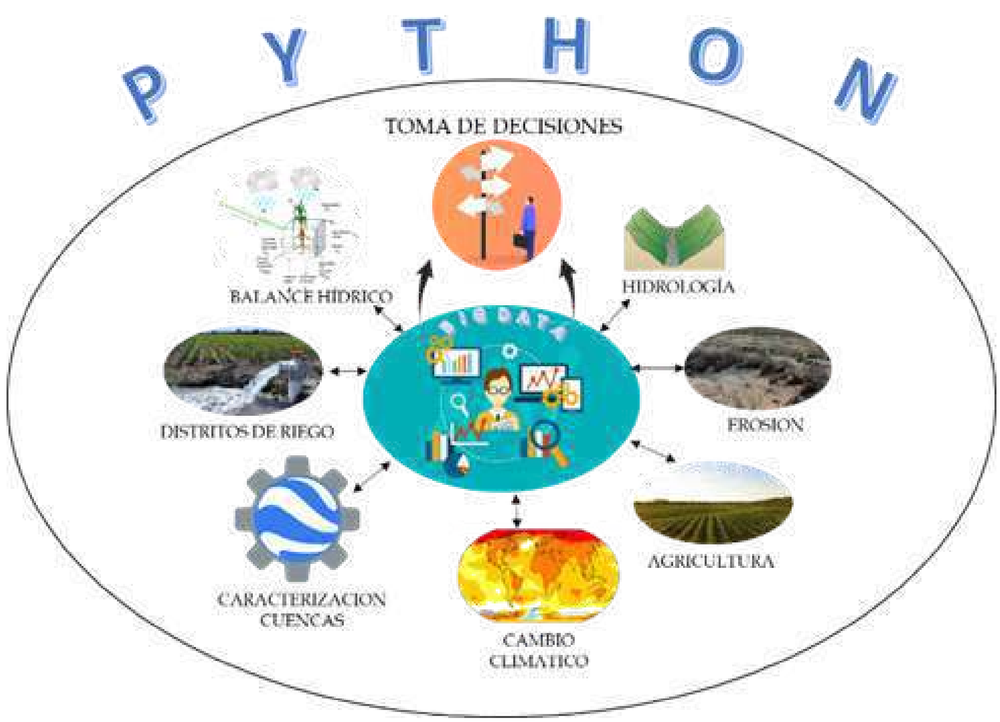

Figure 1. General themes that the Python-based APP considers for the analysis and deployment of water related information

Ignacio Sánchez Cohen
et al

TOPIC	MODEL / INFO GENERATED
CLIMATOLOGY	Time series for each station in a watershed (daily, monthly),
HDROLOGY	Dimensionless hydrograph, Runoff, Index Flow, Aquifers status, Water balance, Watershed - runoff time series (sedigraph time series for selected watersheds), Water balance projections, Link Knowledge Base
EROSION	USLE Watershed-plot, Physical effects matrix
AGRICULTURE	Statistics at municipality level (Yields, crops patterns, Graphical view
CLIMATE CHANGE	Forcings, heating (IPCC-Algorithms)
WATERSEHD CHARACTERIZATION	Google Earth Engine script 23 vegetation and soil indexes at watershed level
IRRIGATION DISTRICTS	Irrigation model for water balance, scheduling and design, statistics of dams (PDF of dam storage), API for daily status of dams.
WATER BALANCE	Crop growth-water balance for rain feed agriculture linked to Knowledge base
DECISION TAKING	Software facilitator

Table 1. Installed capabilities of the computational application

The APP considers the computation of some climate change forcings and its impact on atmosphere heating. The APP also contains a Google Earth Engine script for the computation of 23 soil and vegetation indexes in any of the 756 watersheds of the country. As an example of the system capabilities, through the topic of "Hydrology", the user may obtain the Dimensionless Hydrograph of any watershed given certain input data as curve number, area, path length, precipitation and runoff coefficient. With the use of an API (Advanced Programming Interface), the user may perform the watershed water balance for a given time as well as the seven days prognostic of it. Data deployed in this task are the soil water content, potential evapotranspiration, max and min soil temperature and rainfall. For the seven days prognostic, the system deploys actual evapotranspiration, and soil water content (Figure 2). For having a first appraisal of runoff potential for a given watershed, the system includes an Artificial Intelligence algorithm that uses a database generated with hundreds of runoff-curve number model runs. This algorithm also deploys the decision tree that the approach used to arrive at the resulting runoff value.

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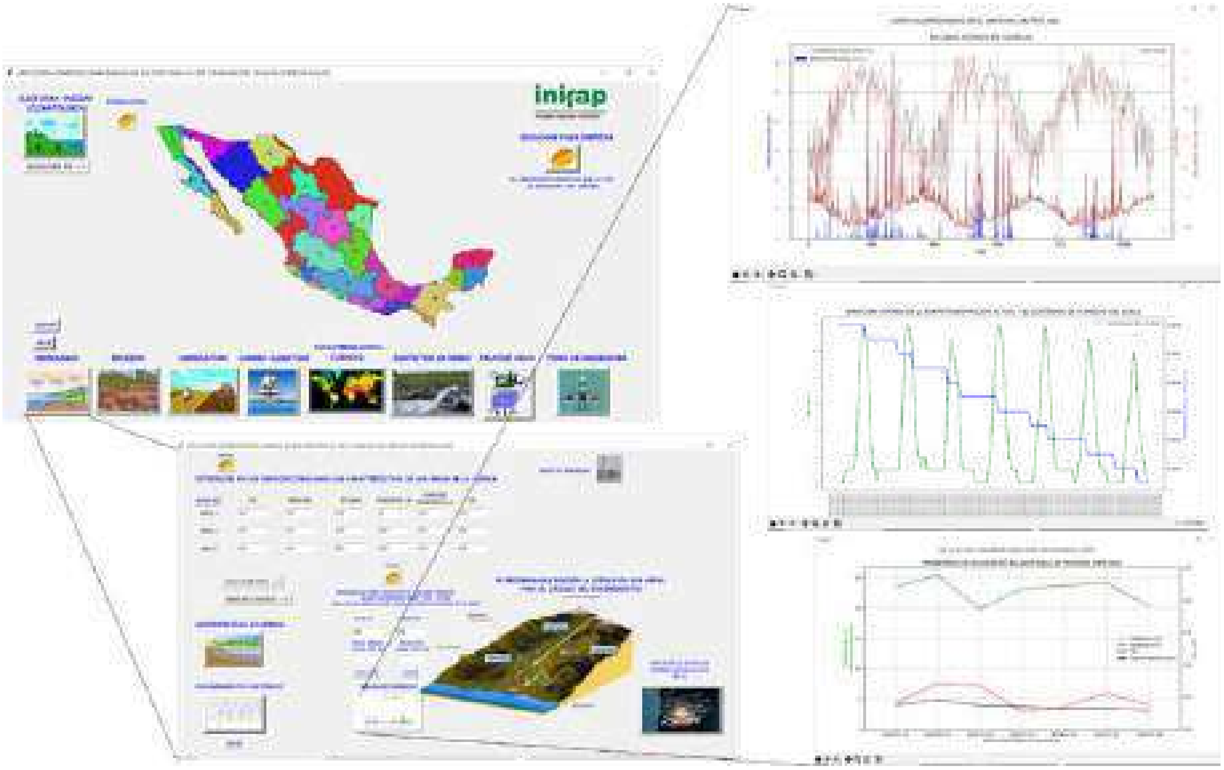
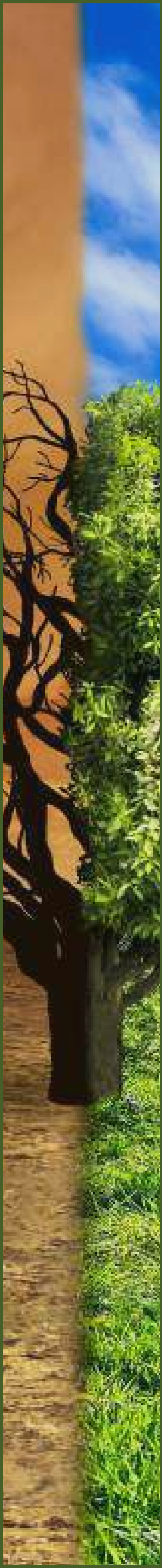


Figure 2. Some computations through simulation models within the theme of hydrology



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CONCLUSION

The platform will serve as support for decisions taking. Link to several databases and the development and use of algorithms to using them is a crucial endeavor within the project. Many simulation models may be included linked to AI algorithms for facilitate its use.

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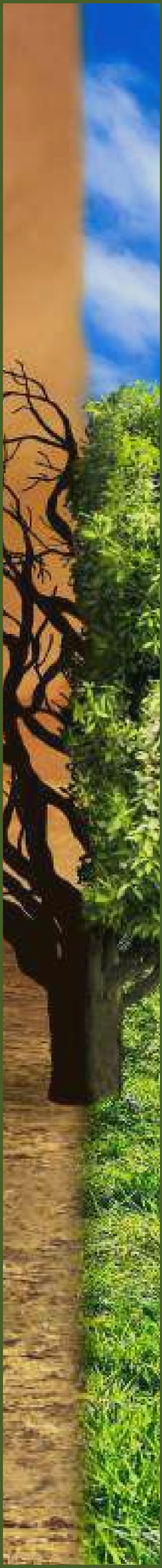

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Methodologies Focused on Determining Water Requirements and Crop Yields

INTRODUCTION

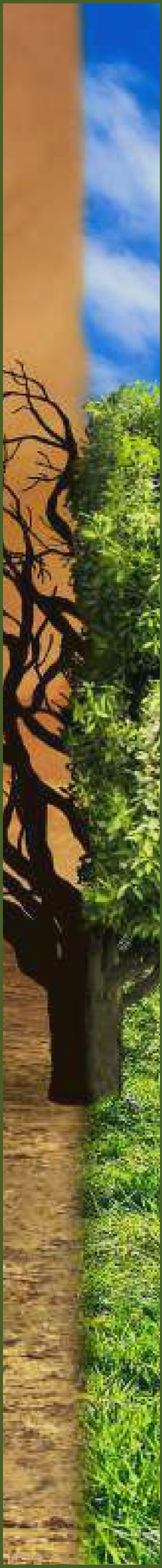
In There is an unquestionable need to achieve greater efficiency in the use of irrigation water since the demands of the urban and industrial sectors are increasing as time goes by. Another factor that causes uncertainty in the availability of freshwater is the phenomenon of climate change, which according to forecasts will cause continuous droughts and exacerbate extreme weather events such as hurricanes, as well as the contamination of freshwater due to the advance of the sea to the continent (Ojeda-Bustamante et al., 2011).

Since the agricultural sector consumes the largest percentage of water in food production, about 70% through agricultural irrigation, it is important to emphasize the increase in achieving greater efficiency in water use and to recover volumes of this resource not for the purpose of using it to increase irrigation areas, but with a focus on the sustainability of the regional future by using only renewable water.

For this reason, the determination of water requirements or water consumption by crops or the actual evapotranspiration and not that of the crop is the one that should be used in agricultural irrigation of different crops to achieve significant savings in water volumes with the efficient use of irrigation technology.

Through time, methodologies for the determination and estimation of the current evapotranspiration of crops have been innovated by means of research and the use of weighing lysimeters, Eddy flow tower, estimation by remote sensing, etc. have been used. Also, the rescue of water volumes with techniques such as deficit irrigation without significantly decreasing yield.

Therefore, the focus of the undersigned is to achieve greater efficiency of water use in production systems through methodological strategies that allow knowing how much and when to apply irrigation water to crops to achieve greater efficiencies in production systems.



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RESEARCH PERSPECTIVES

This line of research is fundamentally focused on generating knowledge and technology to increase the level of water use in irrigation practices in Mexico. It reflects the importance of irrigated agriculture in the country, which is practiced in 25% of the total cultivated area (6.5 million ha) and contributes 50% of the national production. Based on this purpose, methodologies have been developed to determine the water consumption of crops of national or regional importance and of new introduction to quantify their current evapotranspiration under different soil water stresses and their yield response. For which experimental plots have been installed in the field contained in experimental designs and repetitions under the protocol of the scientific method. In this way, their water requirements and yield response have been obtained. These studies are carried out to generate production functions to irrigation water. Thus, their water consumption and response to water stress of basic crops such as corn, beans, wheat, forage crops such as alfalfa, forage sorghum, oats, ryegrass, forage corn and industrial crops such as cotton, sunflower, safflower, canola, kenaf, and vegetables have been obtained. Likewise, evapotranspiration studies have been carried out with a weighing lysimeter, located in the middle part of the experimental field of CENID RASPA INIFAP (Figure 1), with the referred crops with the objective of determining their crop evapotranspiration or maximum evapotranspiration (ETc) to subsequently obtain the crop coefficient Kc which is defined as:
Kc = ETc * ETo-1 ; where Kc= crop coefficient (dimensionless); ETc = maximum or crop evapotranspiration (mm d-1); ETo = reference evapotranspiration (mm d-1), .
To obtain the maximum evapotranspiration of the crops, they were grown under adequate and non-restrictive soil moisture conditions for their good development (Allen et al., 2005). Therefore, the value of Kc varies mainly according to the characteristics of the crop, varying only in a small proportion according to the climate. This variation is resolved by adjusting these coefficients with the determination of Etc. This allows the transfer of standard values of the crop coefficient between different geographical areas and climates (Allen et al., 2005).

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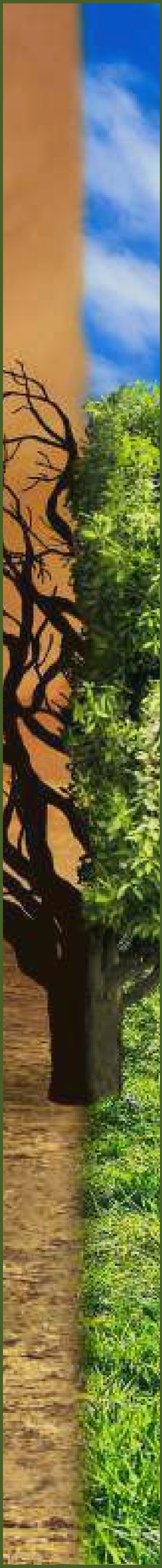
With these studies it has been possible to apply the strategy of deficit irrigation for arid regions and where the fundamental issue is to save water volumes by applying water in a limited way in the growth stages of crops, which are more sensitive to drought. This strategy helps maximize water productivity without significantly reducing yields.

Figure 1. Installation of the crops in the weighing lysimeter of the experimental plot.



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CONCLUSION

It is essential to generate knowledge about crop water requirements and their response as they may be changing with the influence of climate change. In addition, these studies are basic to apply strategies such as deficit irrigation of crops, which allows a sustainable approach by reducing the application of water without significantly reducing yields. It is also important to generate and adjust Kc crop coefficients through Lysimetry, since they are well accepted by producers for being able to program irrigations with sufficient precision in regions that do not have easy access to information resulting from research or climatic data.

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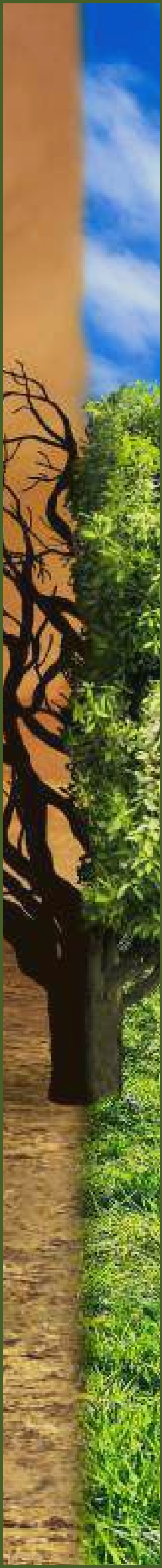

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Remote Sensing and Reanalysis Data applied to irrigated agriculture in Mexico

ABSTRACT

Remote sensing and reanalysis data are producing a change in the way crop monitoring is carried out in irrigated areas, with locally calibrated models it is possible to achieve an efficient use of resources. Vegetation indices allow analyzing agricultural variables related to irrigation, for example, to estimate the phenological development of crops and based on this to define irrigation criteria; crop coefficients (Kc) and evapotranspiration to determine water consumption; monitor yield or leaf area index to calibrate biophysical models of crop growth. Reanalysis data allow obtaining consistent and homogeneous climatic information, which is useful in regions where there is no robust network of meteorological stations, as is often the case in underdeveloped countries.

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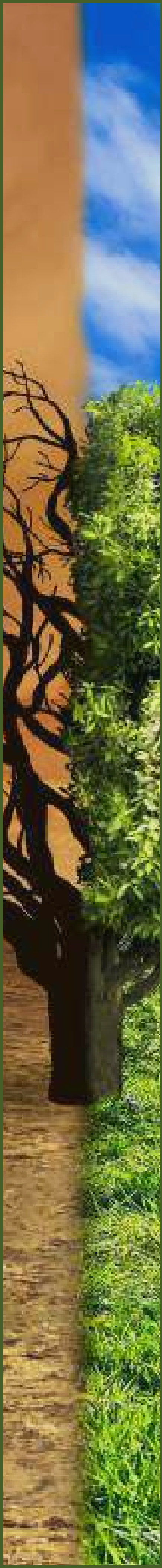
VEGETATION INDICES IN AGRICULTURE

Vegetation indices (VIs) derived from satellite images are simple and effective operations for quantitative and qualitative assessments of various agricultural applications, such as estimating the fraction of vegetation cover, leaf area index, crop coefficient, evapotranspiration, vigor, or growth dynamics of agricultural crops, among others.

One of the most used and implemented indices calculated from multispectral information as a normalized ratio between the red and near infrared bands is the Normalized Difference Vegetation Index (NDVI) (Xue & Su, 2017). However, along the last decades, several IVs have been developed, in order to improve vegetation response and minimize the effects produced either by soil, brightness, shade, soil color, etc. Some of these IVs can be observed in Table 1, where the main agricultural applications are shown.

Application	IV	studies
YIELD	DVI (Richardson & Wiegand, 1977) EVI2 (Jiang et al., 2008) GNDVI (Gitelson et al., 1996) WDRVI (Gitelson, 2004)	(Bolton & Friedl, 2013)
Crop coverage	GNDVI NDVI (Rouse et al., 1973) VARI (Gitelson et al., 2002) TSAVI	(Jiapaer et al., 2011; Yang et al., 2017)
Leaf area index	ARVI (Kaufman & Tanré, 1992), EVI (A. Huete et al., 2002), MSAVI2 (Qi et al., 1994), MTVI (Haboudane et al., 2004) OSAVI (Rondeaux et al., 1996)	(Baret et al., 1989; Gitelson et al., 2007)
Biomass	RDVI (Roujean & Breon, 1995) SAVI (A. R. Huete, 1988)	(Gitelson et al., 2003; Kross et al., 2015)
Phenology	NDVI EVI	(Guzinski, 2010; Sifuentes-Ibarra et al., 2020; Viña et al., 2004)
Evapotranspiration	NDVI EVI	(Glenn et al., 2010)
Crop Coefficient	NDVI SAVI WDRVI	(Pôças et al., 2020; Rafn et al., 2008; Singh & Irmak, 2009; Zhang et al., 2019)

Table 1. Vegetation indices (IV) applied to agriculture.



There are different tools to extract IVs from different surfaces, among them is the VICAL tool (Jiménez-Jiménez et al., 2022), which allows estimating IVs derived from LandSat and Sentinel-2 images or directly using platforms such as Google Earth Engine. Using the VICAL tool, with the vegetation indices, it has been possible to automate processes to calculate the phenology of Maize using Landsat images.

REANALYSIS DATA IN AGRICULTURE

In various agricultural applications, meteorological input variables are demanded, which are usually not available in the required frequency and quality. This is often the case in developing countries, where there is not a high density of weather stations to measure the variables of interest. In Mexico, climate information for agricultural application can be obtained mainly from the national meteorological service (SMN) and the National Network of Automated Agrometeorological Stations of INIFAP (https://clima.inifap.gob.mx/lnmysr/Estaciones/Mapa) or from private meteorological stations. However, it happens that not all variables are measured for a certain application, for example, solar radiation is not measured in certain stations of the SMN, this variable is useful to calculate the reference evapotranspiration (ETo), or the data are not available online as it happens with INIFAP stations.

Reanalysis data (RD) is an emerging alternative that eliminates the need for a robust network of weather stations and can be used to deal with insufficient observations either to backfill or to obtain continuous data. RD arise from the assimilation of long time series of observations with an invariant assimilation system. Unlike gridded data derived from geostatistical spatial interpolation, the spatial structures of meteorological variables (such as temperature, surface pressure, and water vapor) in RDs are the result of the integration of physical laws embedded in the numerical model (Pelosi et al., 2020).

Several historical reanalysis datasets available provide daily or hourly climatic data. Most of these datasets, commonly, are freely available on web platforms published in regular grid or grid formats, lagged months or days from the present and can be automatically downloaded from sources via python-style scripts, incorporated into geospatial processing frameworks such as ArcMAP or python-GDA scripts (Allen et al., 2021).Some of the grids, included in Table 2, are available in near real-time on Google Earth Engine.

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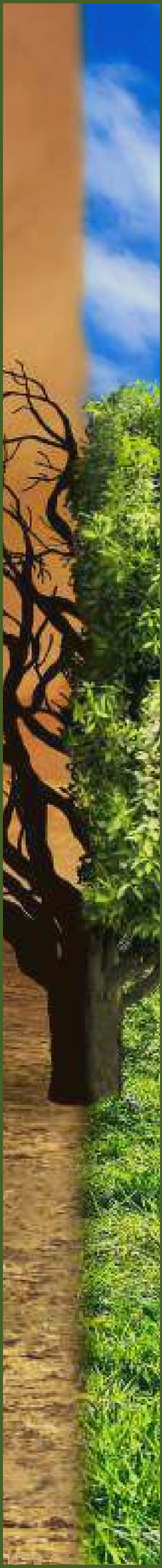
No	dataset	Resolution			Period	Coverage	Variables*
		Spatial (km)	Spatial (°)	Temporal (hr)			
1	CFSv2	~22 latitude	~0.2	6	1979 - present	Global	Maximum, minimum and average temperature, specific humidity, solar radiation, wind speed, rainfall, soil moisture at different depths.
2	GLDAS 2.1	~28	1/4	3	2000 - present	Global	Maximum, minimum and average temperature, specific humidity, solar radiation, wind speed, ET, transpiration, precipitation, surface runoff, soil moisture at different depths.
3	NLDAS-2	~14	1/8	1	1979 - present	CONUS	Temperature, specific humidity, solar radiation, wind speed, precipitation.
4	RTMA	2.5	1/24	1	2011-present	CONUS	Temperature, dew point temperature, total cloud cover, wind speed, precipitation.
5	NP	55	1/2	24	1989-present	Global	Maximum, minimum and average temperature, relative humidity, dew point temperature, specific humidity, solar radiation, extraterrestrial solar radiation, wind speed, precipitation, soil moisture at different depths.
6	ERA5-LAND	~11	0.1	1	1981-present	Global	Maximum, minimum and average temperature, specific humidity, dew point temperature, solar radiation, wind speed, precipitation, surface runoff, total evaporation.
7	MERRA2	55	1/2	1	1980-present	Global	Temperature, specific humidity, surface temperature
8	CFSR	55	1/2	6	1979-present	Global	Maximum, minimum and average temperature, soil temperature, specific humidity, solar radiation, wind speed, precipitation, surface runoff, soil moisture at different depths.

**Only reference is made to the main useful variables in agriculture*

Table 2. Resolutions and coverage of some reanalysis datasets.

In recent years, there has been a trend to reduce the spatial scale of RDs, this is important, although high spatial and temporal resolution do not always provide high accuracies with respect to measured data (Blankenau et al., 2020). RDs can provide higher accuracies for certain applications due to their ability a variable more accurately; therefore, an evaluation of different reanalysis data in a specific application is necessary whenever the possibility exists. Reanalyzes help to focus attention on those observations needed to address key uncertainties in agriculture, providing guidance for future observing systems (Rood & Bosilovich, 2010). In several works, we have found that RDs can be used with some local calibration, to separate the variables that give us the most precision from those that need some adjustment. Alternatively, combine different datasets, in order to improve the accuracy of a certain variable.



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CONCLUSION

Remote sensing and RD can be coupled for use in applications such as irrigation scheduling, calculation of degree days of development, water footprint estimation, biophysical modeling of crops or yield estimation, where several meteorological input variables are demanded.

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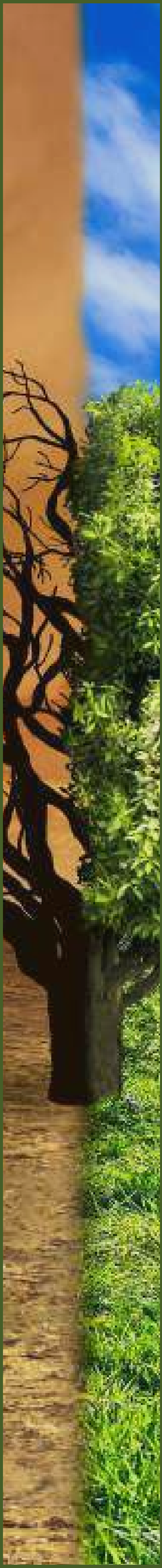

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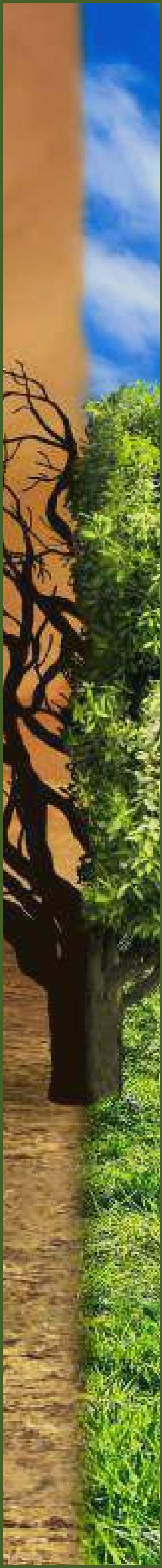

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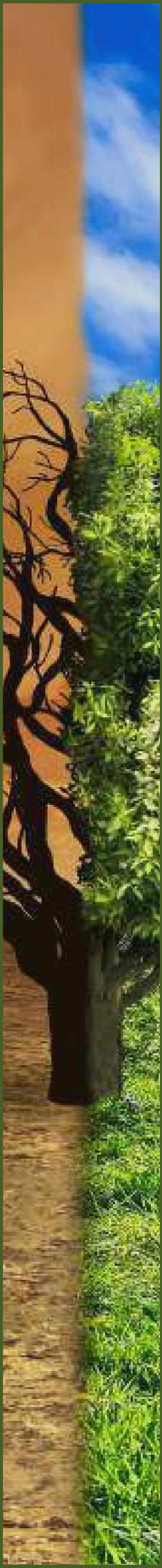


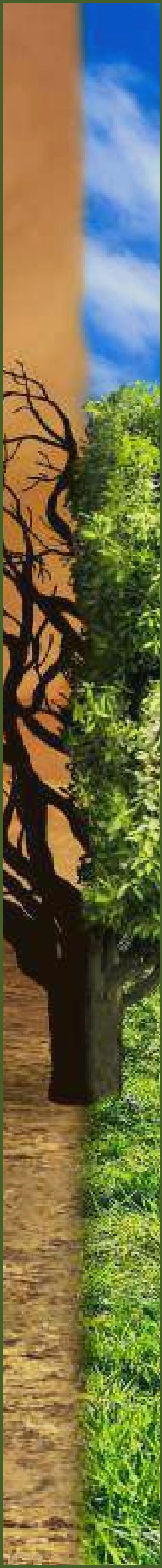
Rafael Alberto Guajardo Panes
Gabriel Díaz Padilla

INIFAP researchers in the Climate Vulnerability Program

Effects of Climate Change in Veracruz Case Study: Orange and Coffee Cultivation

INTRODUCTION

In the state of Veracruz, agriculture is a fundamental pillar of the economy and cultural identity. However, climate change is rapidly transforming the region's agricultural landscape, especially when it comes to orange and coffee cultivation. Variations in temperatures and precipitation patterns are putting pressure on these crops, posing significant challenges for producers and communities who depend directly or indirectly on them for their livelihoods. The increase in temperatures in Veracruz is affecting the physiology of orange and coffee crops, altering the flowering, ripening and fruiting cycles. In addition, warmer temperatures can create conditions conducive to the proliferation of pests and diseases that influence the health of the trees and, consequently, the quality of the fruits. On the other hand, variations in precipitation patterns are influencing the vulnerability of these crops. On the other hand, prolonged droughts can cause water stress in orange and coffee crops, negatively affecting their growth and development. At the same time, heavy rain events and storms can cause flooding and soil erosion, damaging plantations and compromising the quality of the harvest. This work explores how variations in temperature and precipitation are impacting the areas conducive to the development of orange and coffee crops in Veracruz.



Rafael Alberto Guajardo Panes
Gabriel Díaz Padilla

THE PROPOSAL

It is essential to consider information on climate change scenarios in the state of Veracruz because it provides a more complete and accurate understanding of how the climate in the region is expected to evolve in the future. This is crucial for making informed and proactive decisions in various areas, including agriculture, natural resource management, urban planning, public health and disaster resilience. Some specific reasons to consider this information include: planning and adaptation, risk management and sustainability with which it is possible to offer a vision of possible variations in key climatic factors such as temperatures, precipitation and extreme events, being vital for orange and coffee producers. . For the present case, information on variations in precipitation and temperature offered by the Informatics Unit for Atmospheric and Environmental Sciences of UNAM (UNIATMOS) was consulted on the portal https://atlasclimatico.unam.mx/cmip5 /visualizer in climate scenario is the near scenario (2015-2039) with the HadGEM2-ES model with spatial resolution of 200x133 km considered as the appropriate pattern of bimodal behavior of precipitation and its variability (Cavazos and De Grau, 2014) Likewise, the SSP2-4.5 emissions scenario was considered with representative paths of radiative forcing concentration of CO2 emissions. This model was considered because it is an intermediate emissions scenario, in which anthropological activity is presented without changes to how it is currently carried out. On the other hand, the agroecological requirements for the establishment of the crop were considered according to what was proposed by Díaz et al. (2012). Finally, cartographic products were obtained through map algebra in which the spatial dispersion of the ideal areas for the development of the crops in question was observed and where the surfaces that decreased, increased, or remained stable under the conditions were quantified. of temperature and precipitation for the establishment of orange and coffee crops in the state of Veracruz (Figure 1).

Rafael Alberto Guajardo Panes
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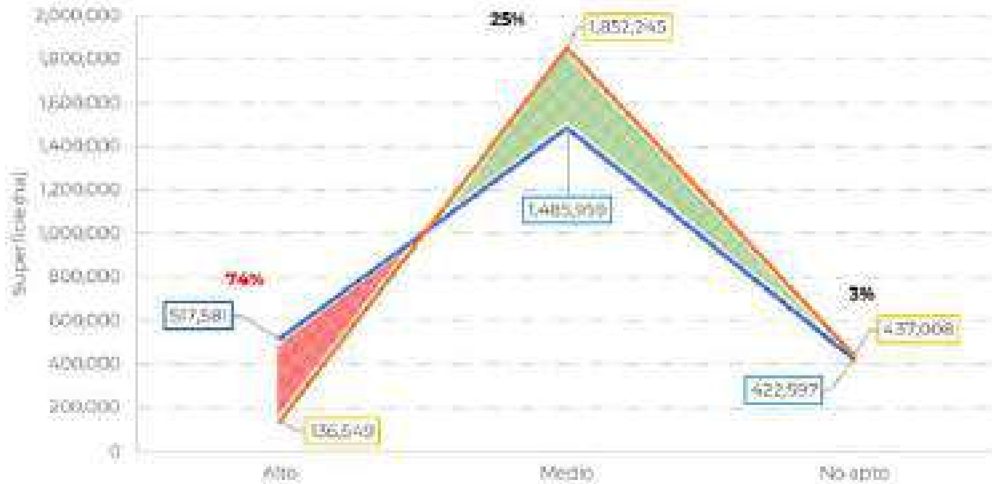
a)



b)

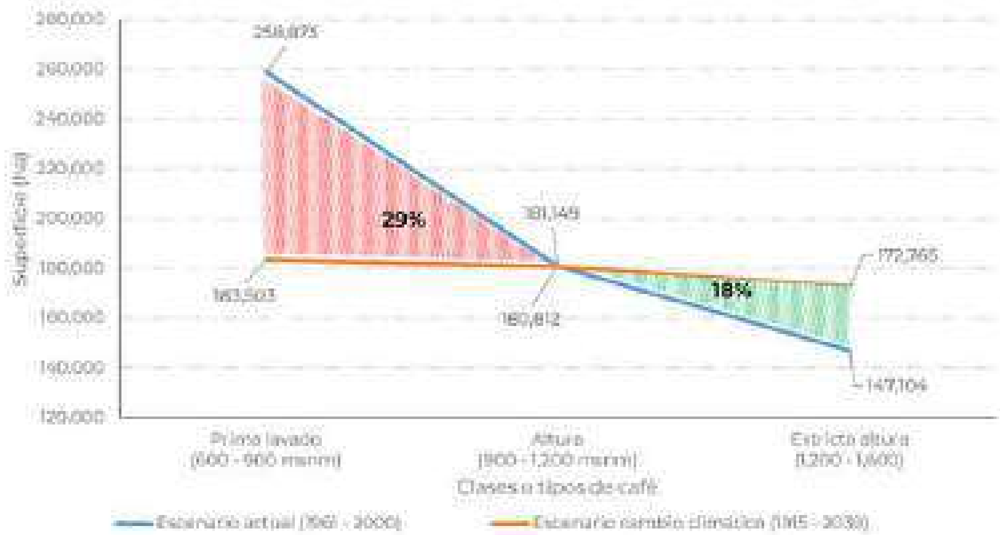
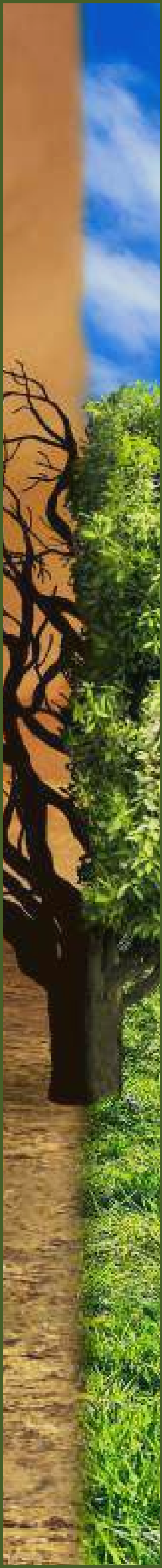


Figure 1. Variation in surface area suitable for establishing the cultivation of a) orange and b) coffee in the state of Veracruz.

The information described here is ideal for producers, technicians and decision makers in the orange and coffee production chains to anticipate climate impacts and design effective adaptation strategies. In addition, understand future scenarios to identify and evaluate specific risks for these crops, such as the alteration of growth cycles, the proliferation of pests and diseases, as well as the availability of water.



Rafael Alberto Guajardo Panes
Gabriel Díaz Padilla

CONCLUSION

The integration of climate data into agricultural planning promotes sustainable practices, ensuring the resilience of orange and coffee crops in the face of climate challenges and guaranteeing their continued production in harmony with the environment and future generations.

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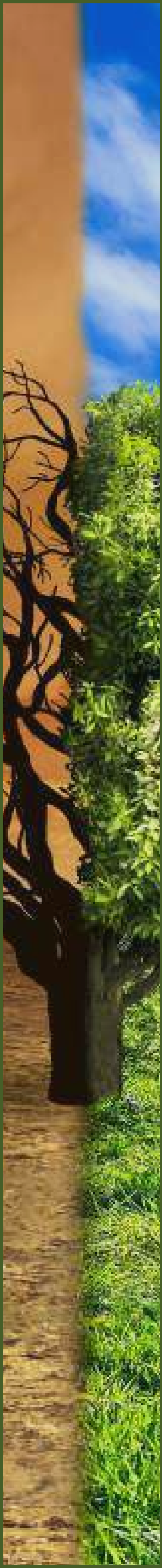


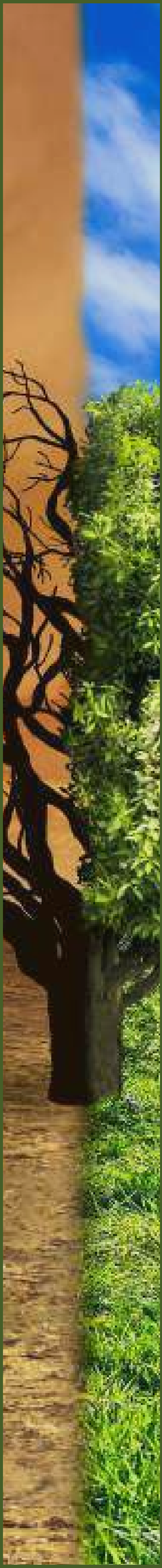
Walter López Baez

Researcher and Leader of the National Watershed Management Program of the - INIFAP

Integrated Watershed Management for Sustainable Use of Natural Resources and Adaptation to Climate Change with a Social Approach

INTRODUCTION

Climate change is a reality and one of the main current concerns of humanity. In Chiapas and other states of Mexico, the effects caused by changes in rainfall and temperature patterns are increasingly frequent and intense, such as loss of human life and negative effects associated with food security, family income, water supply, livelihoods, supply of ecosystem services and damage to the economy as a whole. This damage becomes more important in areas with hilly topography in which the consequences of inadequate management of their resources, especially in their upper parts, are manifested in the lower parts when extreme precipitation events occur. In this context, the concept of integrated management of watersheds has recovered importance as a suitable way for the sustainable use of natural resources and risk reduction of disasters. However, there exist still limitations to the use of the watershed as a unit for planning and action, due to mainly the missing methodologies to intervention that include the organized participation of all interested actors, especially the local population.



Walter López Baez

APPROACH

In this context and to reduce the vulnerability of natural and anthropogenic systems to the adverse effects of climate change, an alternative model is required to comprehensively and systemically manage natural resources in a common territory, with the participation of user society and government agencies through an integrative and environmentally friendly approach. The proposed model considers the next elements (Figure 1):

- The integrated and systemic management of development in the territory, acknowledging that climate change affects all areas of human life and cannot be understood with actions isolated and dispersed.
- The use of the watershed as the unit of planning and action, acknowledging that water is one of the most affected resources by climate change. For the intervention, watersheds are divided into micro basins, which are prioritized using environmental, social, economic, and productive indicators. In the prioritized micro basins, a diagnosis and planning process is carried out with the participation of communities, this includes the family necessities, livelihoods, the basis of natural resources, the supply of environmental services, and the climate change damages. Action plans for each micro basin are elaborated, which include programs for food safety, conservation agriculture, water security, soil conservation in productive areas, regenerative livestock (productive restoration), and existing forest conservation.
- The capacity development of the population, organizing it in Intercommunities Groups of Territorial Action (IGTA), to enable the management development based on collective action, common interest, and organized participation.
- A private-public funding mechanism that guarantees the continuity of actions under the premise of co-responsibility, concurrence, participation, and results in the resources application.

The intervention model permits understanding the hydrological connectivity that exists among watersheds, municipalities, protected natural areas, productive areas, and the infrastructure for sustainable development, by making it clear that the conservation of watersheds must be carried out throughout territorial strategic projects and not with sectorial, dispersed and isolated actions that produce few o null impact, and that generally promote individual earnings at the expense of collective earnings.

Walter López Baez

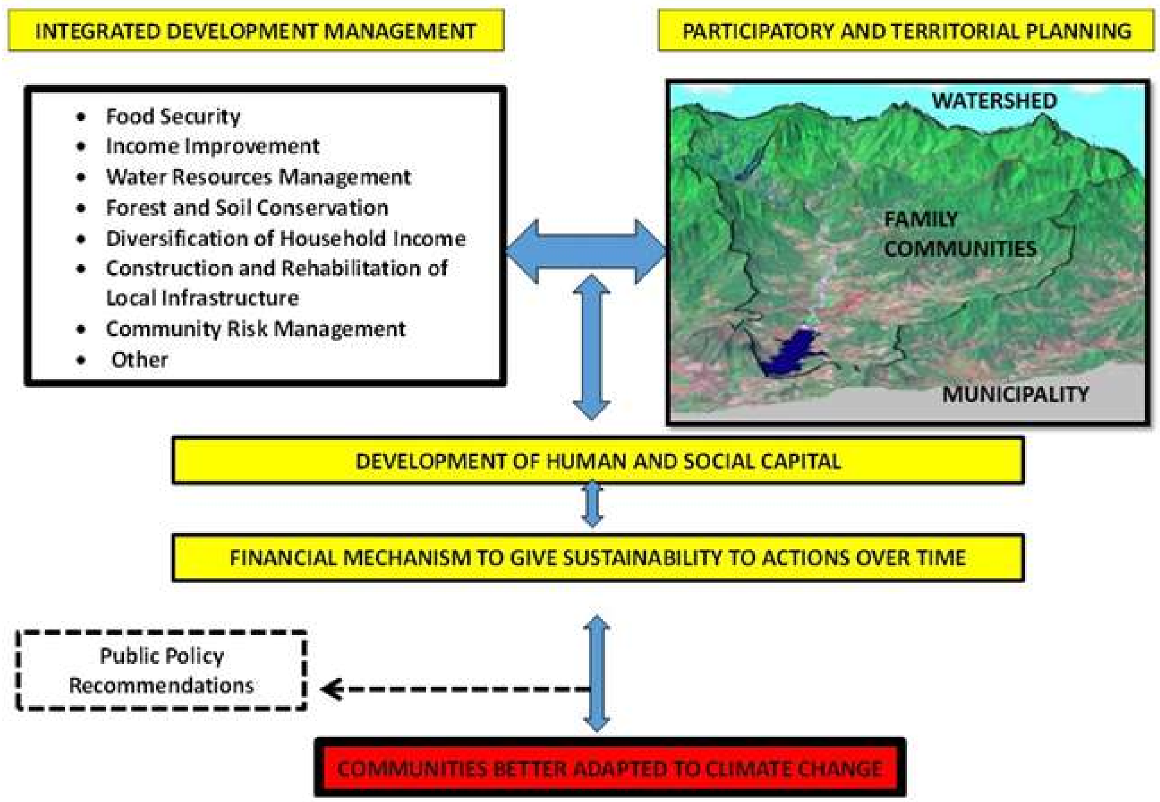


Figure 1. Components of the intervention model.

This model has been evaluated in the Sierra Madre de Chiapas with the participation of INIFAP, IICA, Fondo de Conservation El Triunfo, and The Naturale Conservancy.

In 2022, the Comisión Federal de Electricidad (the national agency for power generation in Mexico, CFE) requested INIFAP to apply our model for designing a proposal for the integral and sustainable management of the water provider watersheds to the Angel Albino Corzo Central Hydropower; to identify intervention areas that permit these watersheds, to continue providing water properly for the generation of electricity, and at the same time, that the population (especially the one that inhabits in the upper and medium parts) can continue obtaining the livelihood from it productive activities.

Walter López Baez

CONCLUSION

The intervention model highlights the importance of addressing climate change with a comprehensive, systemic, participatory, territorial, and transdisciplinary approach. The main result is to create communities better adapted to climate change. Other expected results are to recover trust and confidence in the planning processes, the positioning of the watershed approach both in public policy and in the community use of natural resources, and the strengthening of government action with the participation of private institutions in territorial strategic projects.

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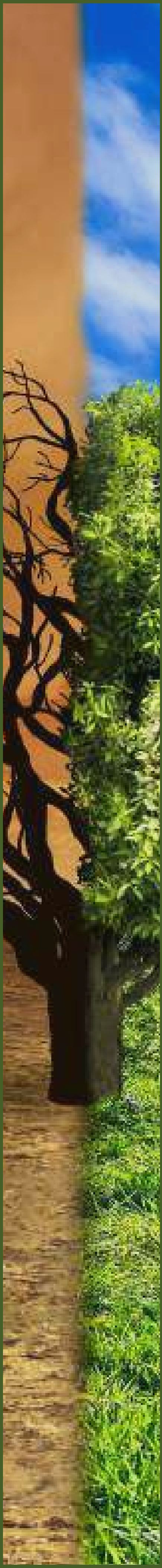


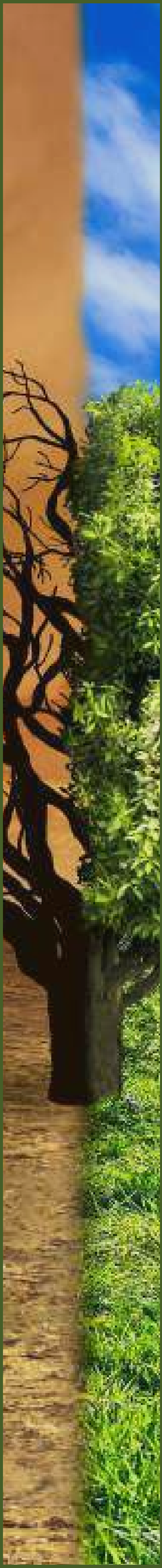
Daniel Moriasi

Research Hydrologist – USDA ARS Oklahoma and Central Plains Agricultural Research Center, El Reno Oklahoma

General Overview of the Soil and Water Assessment Tool (SWAT)

ABSTRACT

The soil and water assessment tool (SWAT) (Arnold et al. 1998; Arnold et al. 2012) is a continuous-time, physically based watershed- scale hydrologic and water quality model developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in watersheds with varying soils, land use, and management conditions. It has been widely used to evaluate the effects of alternative management decisions on water resources and nonpoint-source pollution in large river basins, among other uses (Gassman et al. 2007; Douglas-Mankin et al. 2010). SWAT undergoes continuous development as science evolves to meet the new research needs. The general model structure, global applications, and current development status, including the development of the SWAT+ model, will be presented.



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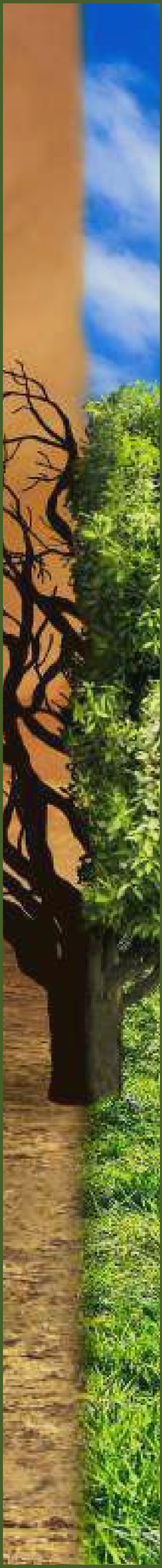


C. Alan Rotz

Pasture Systems and Watershed Management Research Unit
Agricultural Research Service of the US Department of Agriculture

Integrated Farm System Model: a Tool for Evaluating Alternative Beef and Dairy Production Systems

INTRODUCTION

The Integrated Farm System Model (IFSM) was developed out of the need for a research tool for integrating the many components of a farm to study the effects and interactions of changes in production strategies. The model can be used to study common cropping systems found in the US, but its primary purpose is to study dairy and beef production systems. The model has been under development, verification, and application for over 40 years. It has had many applications from the evaluation of forage production systems to quantifying the environmental impacts of all beef cattle and dairy operations in the US. IFSM is primarily used for production systems in the US, but it has also been applied in Canada, Europe, New Zealand, and Brazil. Although primarily a research tool, IFSM is also used in education.

C. Alan Rotz

APPROACH

The IFSM uses process-level simulation to predict whole-farm performance, economics, and environmental impacts of production systems. The model simulates crop production, feed use, animal production, and the return of manure nutrients back to the land for up to 25 years of weather for a long-term assessment (Rotz et al., 2022). Daily growth and development of crops are a function of weather and soil water and N available. Simulated tillage, planting, and harvest operations determine labor, fuel and other resources used, timeliness of operations, crop losses, and nutritive quality of feeds produced. Animal feed intake, production, and nutrient excretion are a function of the type and nutrient contents of the feeds fed.

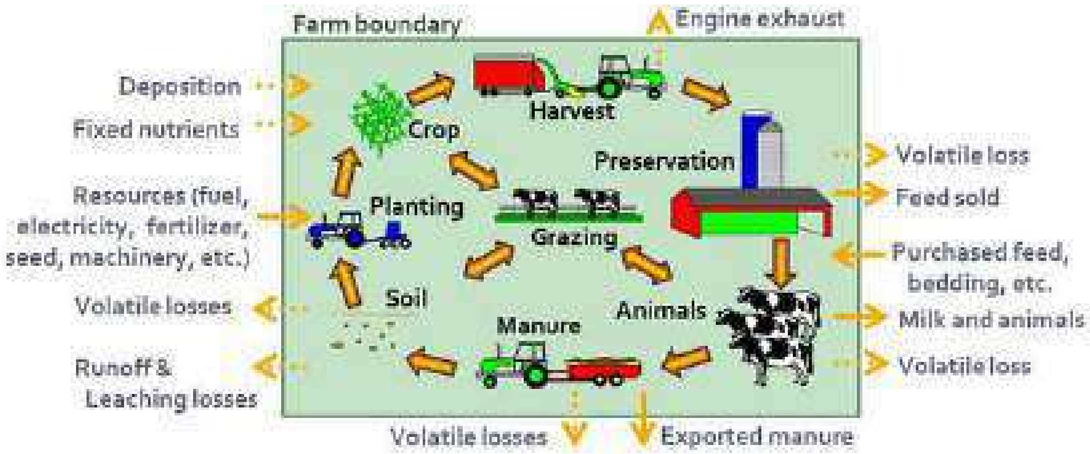
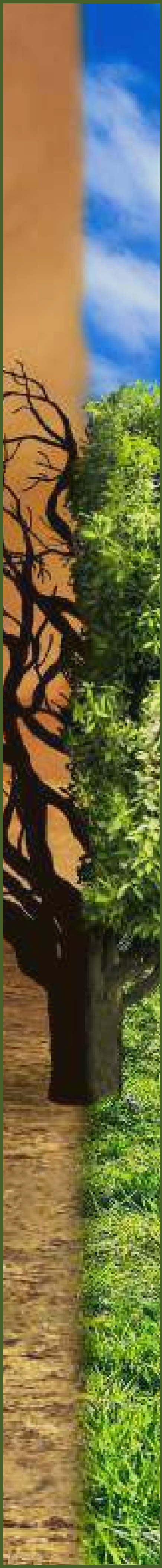


Figure 1. IFSM provides a process-level simulation of whole farm systems.

Nutrients (N, P, K) and C are tracked within the model to predict losses to the environment and whole farm balances (Rotz et al., 2022). Paths of N loss include NH3 volatilization, N2O, N oxide (NOx), and dinitrogen emissions through nitrification and denitrification processes and engine emissions, and NO3- losses through leaching and runoff. Carbon emissions include CH4 from enteric and manure sources along with biogenic CO2. Anthropogenic CO2 emissions are released through fossil fuel combustion and the decomposition of lime and urea fertilizer. Other simulated losses include sediment erosion and runoff across farm boundaries of sediment-bound and dissolved P. Reactive VOC emissions are predicted using a mass transfer model and estimated initial concentrations of important VOCs when silage or manure are exposed to ambient air. Emission processes are modeled using dynamic relationships influenced by temperature, wind speed, precipitation, soil conditions, and management practices.



C. Alan Rotz

Whole-farm mass balances of N, P, K, and C are the sum of nutrient imports in feed, fertilizer, deposition, and fixation, minus exports in losses, manure leaving the farm, and feeds, milk, and animals sold.

IFSM output includes a cradle-to-farmgate life cycle assessment (LCA) for greenhouse gas emissions, fossil energy use, blue water consumption, and total reactive N loss. This includes impacts on the production of resources used such as fuel, electricity, fertilizer, purchased feeds and supplements, purchased animals, machinery, seed, and pesticides. The LCA includes both direct impacts of the production system, as well as indirect impacts caused by the production system that occur outside the operation. Bluewater is freshwater from ground and surface water sources, which is primarily water used for irrigated crop production but also includes that used for cleaning, drinking, and cooling of cattle. Allocation is also used to remove environmental impacts associated with farm coproducts.

Recent applications of the model have included national assessments of the environmental impacts of beef cattle and dairy production in the US (Rotz et al., 2019; Rotz et al., 2021). By modeling representative operations across regions of the country, total impacts were determined by summing the impacts of individual operations weighted by their contribution to the total production of cattle or milk for the country. Farmgate data generated by IFSM has also been linked to other LCA software to study the full life cycle impacts of beef and milk including transportation, processing, retail, consumers, and waste created (Putman et al., 2023).

IFSM is also used to study the effects of projected future climate on crops, beef, and dairy systems (Castano-Sanchez, 2022; Veltman et al., 2021). Projected climate files created from down-scaled data generated by global climate models are used to simulate farms under future climate. Projected changes in ambient temperature and precipitation for various representative concentration pathways of greenhouse gases can be used to evaluate effects on future farm performance, profitability, and environmental impact. Various changes in management and technologies used on the farm are studied to help adapt farms to the changing climate.

Current work focuses on evaluating strategies for mitigating the environmental impacts of operations for current and future climate. Using this integrated model, strategies can be evaluated independently or in combination providing comprehensive assessments of the potential benefits of available strategies and potential future technologies (Veltman et al., 2021). Simulated data are used to prioritize the assessment and application of potential mitigation strategies.

C. Alan Rotz

CONCLUSION

IFSM is primarily a research tool for comprehensive assessments of crops, dairy, and beef production systems with some use as an educational aid. The model has been verified and applied to many applications over its history where recent applications focus on long-term environmental impacts of production systems from individual farm to national scales, the evaluation of strategies for reducing the environmental impacts of farms, and methods for adapting farms to future climate.

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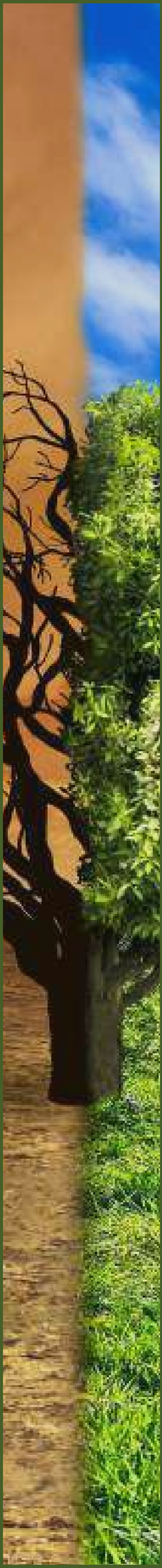

Amber S. Williams

Biological Science Technician at the Grassland, Soil and Water Research Laboratory of USDA-ARS

Almanac: a Tool for International Modeling of Plants, Climate, and Water

INTRODUCTION

ALMANAC is a process-based daily time-step model. It simulates water balance, erosion, nutrient cycling, soil interactions, climate impacts, plant growth and competition through leaf area, light interception, biomass production and stress factors. The model is based on real-world measurements requiring only 4 main components, soil data, weather, management, and crop parameters. Each category has numerous parameters that users can customize to their individual situation and includes options for default information where field data is lacking. ALMANAC was originally developed as a crop model and has expanded its capability to be used in various agricultural and native ecosystem settings, including deserts, forests, wetlands, rangelands, tropical agriculture, and in other countries. ALMANAC has also been used as part of multi-model studies and collaborates extremely successfully with the other 4 models found in Temple, TX. Abilities and publications with ALMANAC regarding climate, wetlands, Mexico and Canada will be discussed.

David C. Goodrich (1)
Mahmoud Saeedimoghaddam (2)
Andrew T. Fullhart (3)
and Numerous other Developers of these tools

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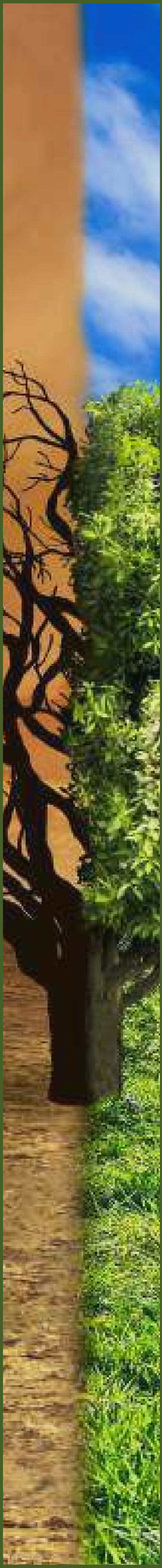
(2) Research Scientist, Department of Land, Air & Water Resources, University of California, Davis, California, USA
(3) Research Scientist, School of Renewable Natural Resources & Environment, University of Arizona, Tucson, Arizona, USA

Making Watershed Models Easier to Apply - AGWA, the CLIGEN Stochastic Weather Generator, and Machine Learning with RHEM

INTRODUCTION

There are a myriad of watershed models underlying the modeling of water quantity and quality, erosion, and decision support systems. Incorporation of greater model complexity, both in time and space, typically leads to greater data needs. It is recommended that we make many of the existing watershed models easier to use versus incorporating additional complexity. Substantial advances have been made using Geographic Information Systems (GIS) and remote sensing to incorporate spatial data into distributed watershed models. This presentation will describe one such system: AGWA, the Automated Geospatial Watershed Assessment tool. In many regions, observations of weather and climate needed to drive watershed models is very limited. Advances in generation and manipulation of climate data for assessing current and future scenarios informed by regional or global climate models are also critical to further application of watershed models for stormwater management and implementation of conservation practices. Machine Learning (ML) also shows promise to advance watershed modeling and an example using the RHEM (Rangeland Hydrology and Erosion Model) is presented.



David C. Goodrich
et al

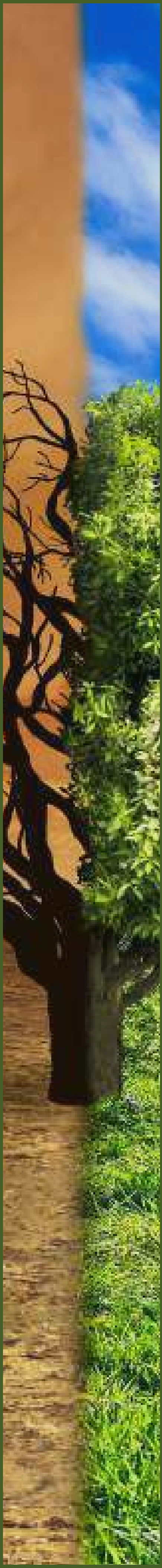
APPROACH

AGWA (Miller et al., 2007; https://www.tucson.ars.ag.gov/agwa/) is a GIS interface jointly, developed by the USDA-ARS, the U.S. EPA, and the Universities of Arizona and Wyoming to automate the parameterization, execution, and visualization of simulation results of a suite of hydrologic and erosion models (RHEM, KINEROS2, and SWAT2005) using nationally available data (USA) or user provided input. It has been under continual development to incorporate new features and functionality and is currently being updated to run in ArcPro. A number of tools within AGWA have been developed for various users to enable scenario analysis. They include the:

- Land Cover Modification Tool
- Multi-Point and Multi-Watershed Tool
- Riparian Buffer Tool
- Post Fire Assessment Tool
- Urban Tool (add-in to ArcMap)
- Channel Diversion – Artificial Wetlands Tool
- Military Disturbance Tool
- Storage/Pond Characterization Toolbox
- Inundation Tool
- Facilitator Export Tool

The AGWA web site (above) includes background, documentations, publications, and tutorials (for ArcMap 10.x) with all spatial data needed for them. On-line resources also include:

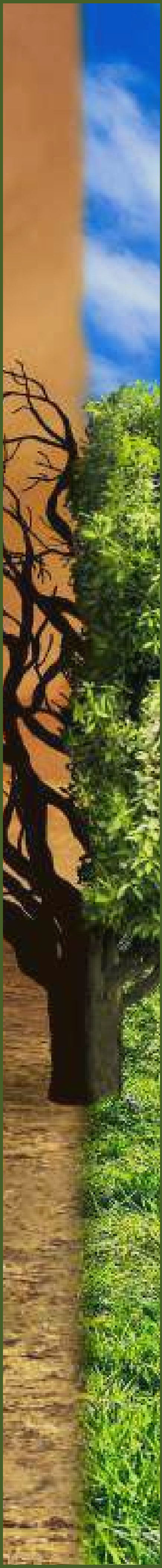
Recorded Presentations of past AGWA Trainings (~1.5 days)
https://drive.google.com/drive/folders/1pzm7ViP3X73YtXx8ETpR_rV9W9GfVXCM?usp=share_link
Tutorial PDFs
https://drive.google.com/drive/folders/11BV5b8Rgf0sOCfVJcoA0ZK8wDL8Z6EF5?usp=share_link
Tutorial Summaries/Descriptions: Tutorial Summaries
AGWA Add-in Installation Instructions for Local Installations with links to required downloads: AGWA Add-In Installation Instructions for Local Installations
AGWA YouTube Channel with Training Videos
https://www.youtube.com/channel/UCNsUT54S36evimKEfmY2CrQ?



David C. Goodrich et al

KINEROS2 (KINematic runoff and EROSion model - is a well-tested physically-based model that simulates the processes of interception, infiltration, surface runoff, erosion, and sediment transport from small- to medium-sized watersheds (https://www.tucson.ars.ag.gov/kineros/). RHEM can be run via the web for a single hillslope (RHEM Web Tool: Rangeland Hydrology and Erosion Model Web Tool (ag.gov). RHEM has also been embedded within KINEROS2 as the infiltration and erosion hillslope engine allowing RHEM to be applied on multiple hillslope elements within a watershed. It should be noted that RHEM requires information about foliar and ground cover fractions that generally must be measured in situ, which makes it difficult to use models like RHEM to produce erosion or soil risk maps for areas over multiple hillslopes such as a large watershed.

To overcome the lack of long-term weather and climate observations, stochastic weather generators can create time series that stochastically generate key weather characteristics present in long-term observations. Fullhart et al. (2024) created a large-scale gridded parameterization for CLImate GENerator (CLIGEN) that fills spatial gaps in the coverage of existing regional CLIGEN parameterizations. Combining the existing coverages with those created by Fullhart et al. (2023) achieves near-global availability of CLIGEN parameters. This dataset primarily covers countries north of 40° latitude with 0.25° spatial resolution. Various CLIGEN parameters were estimated based on 20-year records from four popular global climate products. Precipitation parameters were statistically downscaled to estimate point-scale values, while point-scale temperature and solar radiation parameters were approximated by direct calculation from high-resolution datasets. Surrogate parameter values were used in some cases, such as with wind parameters. Cross-validation was done to assess the downscaling approach for six precipitation parameters using known point-scale values from ground-based CLIGEN parameterizations. These parameter values were derived from daily accumulation records at 7,281 stations and high temporal resolution records at 609 stations. Cumulative precipitation and the annual number of days with precipitation occurrence were both within 5% of ground-based parameterizations. Two sensitive parameters, monthly average storm accumulation and maximum 30-minute intensity, had RMSE values of 1.48 mm and 4.67 mm hr−1, respectively. With these parameterizations, weather and climate can be estimated to drive watershed models for planning and scenario analysis.



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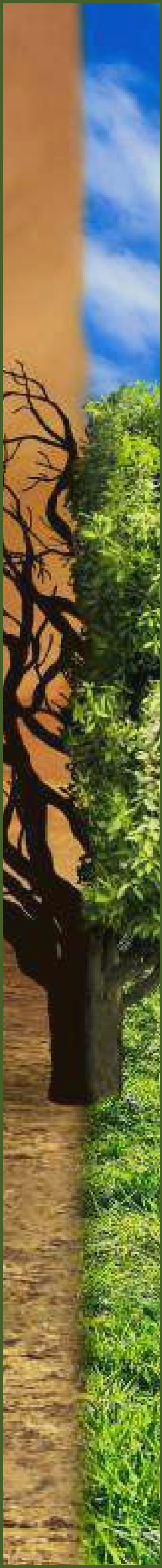
Machine learning (ML) is becoming an ever more important tool in hydrologic modeling. Previous studies have shown ML models have higher prediction accuracy than traditional process-based ones. However, there is another advantage of ML which is its lower computational demand. Saeedimoghaddam et al. (2023) designed an Artificial Neural Network that is able to recreate the RHEM outputs (annual average runoff, soil loss, and sediment yield) with high accuracy (Nash-Sutcliffe Efficiency ~ 1.0) and a very low computational time (13 billion times faster on average using a GPU). The Emulator works accurately for the real-world cases. is statistically similar to RHEM predictions.
To address the difficulty in acquiring ground and foliar cover parameters for RHEM Saeedimoghaddam et al. (2024) developed a deep learning emulator of RHEM that has low computational expense and can be run over large areas. They used ground cover observations from over 60,000 NRI (National Resource Inventory) field sampling sites, in addition to remote sensing time series inputs and antecedent weather and climate, to produce erosion maps. A prediction accuracy on hillslope runoff of R2 ~ 0.9, and on soil loss and sediment yield with a R2 ~ 0.4 was achieved at 66,643 field locations within the USA. They demonstrated how this approach can be used for mapping by developing runoff, soil loss, and sediment yield maps over a 1356 km2 region of interest in Nebraska.



C. Alan Rotz

CONCLUSION

Several methods to aid in applying existing watershed models are presented above. From the GIS perspective the AGWA tool is briefly introduced. It uses nationally available data sets (USA), including global FAO soils to parameterize, execute several watershed models and display model results spatially in the GIS as well as traditional hydrographs and sedigraphs. The near global availability of CLIGEN parameters allows the stochastic generation of daily weather and climate that are statistically consistent with observations. These generated time series can be used as input to drive numerous watershed models. Machine learning enables rapid execution of the RHEM model. Using exiting ground cover and foliar estimates from tens of thousands of Natural Resource Conservation Service NRI field observation locations, ML algorithms were able to predict runoff relatively well at any rangeland location. Prediction of erosion and sediment transport is less certain. Efforts are underway to investigate if additional training data can improve erosion predictions.

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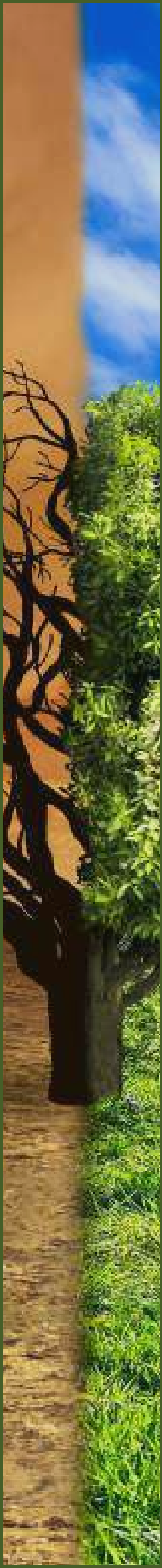

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