Assessment
of annual irrigation applications taking into account long term soil protection

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Introduction

Irrigation requirements are traditionally determined considering only the needs of agricultural plants and the quality of water resources. But irrigation even with a good quality of water can lead to direct and indirect soil degradation. The direct way is rather well known, and affects soils during relatively short periods (several years). In contrast, the indirect way is related to modification of the initial (before irrigation) microclimatic conditions. It is much less studied, realized during relatively long periods (decades), and the prediction of soil quality alteration is rather difficult. The mathematical modeling of long-term soil alteration is usually not very reliable.

Methodology

This approach is based on the geographic law of soil zonality and the establishment of a quantitative relationship between Budyko's radiative index of dryness I_v and regional modal values of a virgin soil property φ_v inside geomorphologically homogeneous soil groups (Volobuev, 1974). The microclimatic index I_v in flat areas with slope less than 1% is calculated as $I_v = Rn_v/LPr$, where Rn_v and Pr are mean annual values of net radiation and precipitation, respectively, and L is the latent heat of evaporation.
The procedure of $\varphi_v(I_v)$ relationship development is shown on the Figure 1.

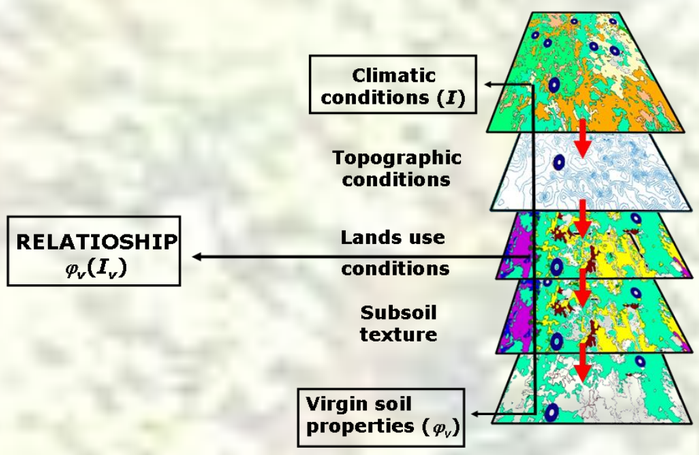

Figure 1. The procedure to develop $\varphi_v(I_v)$

It is supposed that the relationship $\varphi_v(I_v)$ should be conserved in irrigated land as well. In time the property φ of irrigated soil should come into a new equilibrium with the microclimatic condition in irrigated land. It means that if the irrigation with a mean annual amount of water Ir_{agr} changes the microclimatic index from initial value $I_v = Rn_v/LPr$ to $I_{ir} = Rn_{ir}/L(Pr+Ir_{agr})$, where Rn_{ir} is a mean annual net radiation in irrigated land, the soil property φ should be changed gradually from initial value φ_v to φ_{ir} corresponded to a new microclimatic index I_{ir}. The diagrammatic procedure of irrigated soil property φ_{ir} prediction is shown on the Figure 2. As it seen the new soil property φ_{ir} can be better or worse than the initial value φ_v.

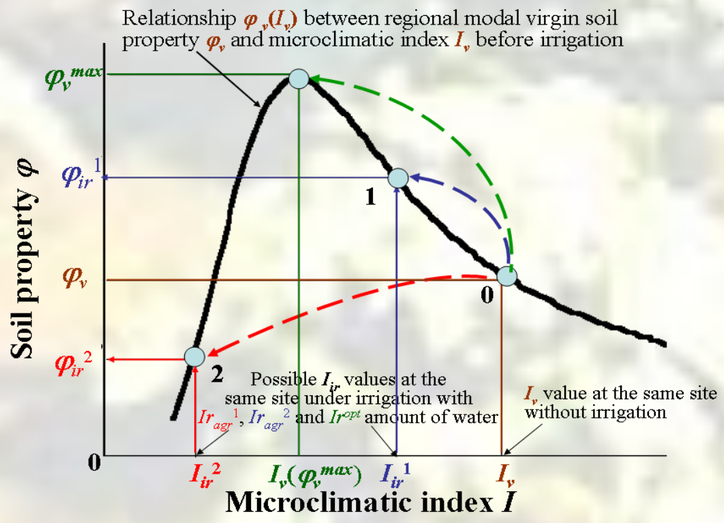

Figure 2. The diagrammatic procedure of irrigated soil property φ_{ir} prediction (without taking into account agricultural practices and water quality). *Iropt* corresponds to the case of microclimatic index formation equal to $I_{ir} = Rn_{ir}/L(Pr+Ir_{opt}) = I_v(\varphi_{vmax})$, where φ_{vmax} is maximal model value of soil fertility property observed in the selected sites with geomorphologically homogeneous soils.

It is possible also to apply an integral soil fertility index F based on organic matter (OM), phosphorus (P) and potassium (K) content and pH value (Pegov and Khomyakov, 1991):

$$F = 0.46\frac{OM}{OM^{max}} + 0.28\sqrt{\frac{P}{P^{max}}\frac{K}{K^{max}}} + 0.26e^{-\left(\frac{pH-6}{2}\right)^2}$$

where OM_{max}, P_{max}, and K_{max} are the maximal values of these properties observed in the selected sites with geomorphologically homogeneous soils.

Analyzing the curve $\varphi_v(I_v)$, it is possible to identify limits of Ir_s in order to prevent soil degradation. Although these values of Ir_s may not be sufficient to obtain a maximum crop yield, they will conserve or improve soil quality indirectly and allow for a most sustainable use of land and water resources.

Results

Some results of this approach application in Mexico are presented.

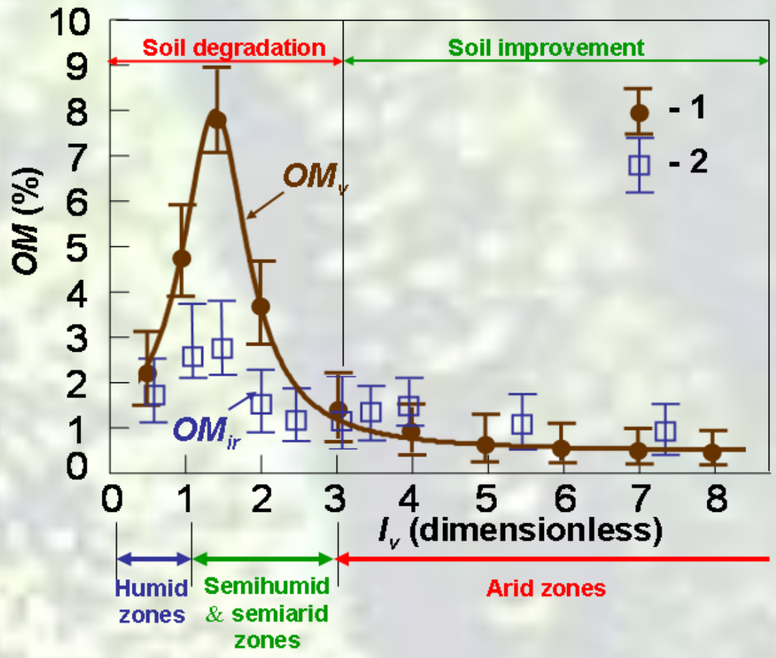

Figure 3. Example of *OM* regional values distribution in virgin not used in agriculture soils (OM_v) and agricultural soils under irrigation (OM_{ir}) depending on climatic index I_v in Mexico; 1 and 2 – modal values and confidential intervals.

Table. Comparison of regional mean annual irrigation water applications *(Ir)* corresponding to agricultural production (Ir_{agr}) and soil improvement (Ir_{opt}) in some Mexican sites

Site (State)	Pr	Ir_{agr}	I_v	I_{ir}	Impact on soil	Ir_{opt}
	mm/year		dimensionless			mm/year
La Antigua (Veracruz)	1266	1568	1.43	0.64	Negative	460
Mante (Tamaulipas)	1164	546	1.55	1.05	Negative	340
Sto. Domingo (Baja California Sur)	648	635	2.10	1.05	NSP	260
Palestina (Coahuila)	595	425	2.30	1.36	NSP	320
El Fuerte (Sinaloa)	511	659	3.07	1.36	NSP	540
Guaymas (Sonora)	224	549	5.95	1.71	Positive	549

Note: **NSP** means "not sufficiently improvement"

Conclusion

1. The irrigation practices even with good water quality may cause slow soil degradation during long terms because of modification of microclimatic conditions of agricultural soil formation.
2. Previous analysis shows that existing surface irrigation of grain crops (maize and wheat) during more than 60 years in some sites of semiarid, semihumid, and tropical humid zones of Mexico cause deterioration of soil fertility in comparison with fertility of not used in agriculture and not irrigated soils on regional scale.
3. It is recommended to realize similar investigation in detail and consider possibilities to reduce in places amount of applied irrigation water in order to conserve soil quality even sacrificing a little bit crop productivity.

Bibliography

Aydarov I.P. 1985. *Regulation of the Water, Salt and Nutrition Regimes of Irrigated Soils.* Ed. Agropromizdat, Moscow (in Russian)

Volobuev V.R. 1974. *Introduction to the Energy of Soil Formation.* Ed. Nauka, Moscow (in Russian)

Nikolskii Yu.N., Bakhlaeva O.S., Contreras-Benites A., and Ordas-Chaparro V., 2002. *Assessment of changes in soil properties as dependent on hydrothermic conditions of plowlands (by the example of Mexico),* Eur. Soil Sci., 35: 1031–1036

Pegov S.A. and Khomyakov P.M. 1991. *Simulation of Ecological Systems Development.* Ed. Gidrometeoizdat, Leningrad (in Russian).