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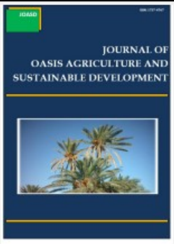

JOURNAL OF OASIS AGRICULTURE AND SUSTAINABLE DEVELOPMENT

www.joasdjournal.org

JOASD

p-ISSN: 2724 – 699X
e-ISSN: 2724-7007

Sustainable Agricultural Development In Sw Tunisia/ Survival Sector And Natural Resources Degradation

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Article info

Article history:
Received 21/01/2022
Accepted 01/04/2022

Keywords: water quality assessment, environmental impacts, agricultural sustainability.

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Conflict of Interest : The authors declare no conflict of interest.

Abstract

Agricultural production relies on numerous interrelated key factors namely irrigation technique, drainage, soil quality … and irrigation water quality that has gained less concern in the agricultural management process. However, the evaluation of the used quality for irrigation especially for long-term use is of crucial importance. Unfortunately, no comprehensive classification based on the assessment of the complex causality links of chemical water composition of the different environmental components that is suitable for the accurate evaluation of the used quality at a local particular scale was found.
Thus, to gain an overall impression of the different methods and approaches a review of the previously published diagrams in the light of the effectiveness and representativeness of the obtained results about the various factors related to farming practices and land characteristics is required. Hence, the purpose of this paper is to represent new diagrams used in future studies as classification approaches. New classification techniques are introduced and described based on the previously used approaches coupled with the consideration of variables soil physic-chemical properties and climate conditions. The resulting schema is used to classify a variety of different approaches operating at multiple levels of characteristics and interaction levels (structure, texture, permeability ...).

1. INTRODUCTION

The efficiency of the irrigation process is closely linked to the infiltration function of soil and permeability-infiltration value (Walker and Skogerboe 1987; Emdad et al. 2006) that may illustrate a relative coefficient of variation up to four for seasonal variability and local scale (Eilers et al. 1983). This variability is controlled by different factors related to progressive pores sealing, soil moisture content before and after irrigation, and management practices …..(Rania et al. 1998; Dhaouadi et al. 2020; Besser et al. 2021). The unstable evolution of these parameters may greatly reduce the performance of farming practices and management efficiency.
However, agricultural systems are closely related to local and temporal aspects principally water composition and land use proprieties (Nunez et al. 2010). The assessment of irrigation water quality suitability to different uses to consider the potential impacts is an important subject of study for both agricultural suitability and ecological value and the stability of socio-economic dimensions of the agro-based regions.
The potential risks of the irrigation water quality on soil physic-chemical proprieties infiltration, aeration ratio, and irrigation application efficiency have been modally discussed. However, the relative effects of quality criteria and indices on soil profile, structural proprieties irrigation performance, and irrigation scheduling have not been widely studied under the spatiotemporal variability of field conditions. Thus, through the analysis of diverse standards literature and different sources of information, it is important to illustrate the need to pursue an alternative approach for the respective purposes of classification and management processes.

Indeed, besides the increasing implementation of consecutive national and international directions concerning water-saving plans and agricultural management and land remediation strategies, the stakeholders, landowners, residents, and scientific committee are not sufficient from the emerging degradation issues that have reached most of the agro-based areas irreversible levels.

Currently, numerous farmers especially in hot dry areas where the quasi-total dependency of agricultural on irrigation of supplied mainly by deep confined and semi-confined groundwater resources have indicated that the variation of the productivity and the emerging environmental issues within the same agrosystems represent the main constraint for effective management. Thus, an increasing awareness exists on the treatment of soil fertility issues at more small scale and to evaluate its spatial variation with accuracy (Ott 1978; Funcume 2002; Toled and Nicollela 2002; Almeida and Schwarzbold 2003; Andrade et al. 2005). Giving the quasi-total dependency on agriculture for a large part of countries amplified by the present-day challenging times where national productivity and food security have supported the multi-sectoral efforts to overcome the COVID pandemic (Chudik et al. 2020; FMCBG 2020; Kim et al. 2020; Mahler et al. 2020; OECD 2020)., economic, social and health constraints, applying interdisciplinary and mainly international established standards adapted to national and even regional scale including the large part of environmental physic-chemical key parameters engineering context, and the quality of the final product is required. Thus, to guarantee sustainable agriculture activities despite the unpredictable climate variations, encouraging efforts of monitoring water quantity used for irrigation are currently appreciated, however, less concern is generally given to quality suitability for irrigation purposes and despite the numerous previous data published about the analysis of water quality evolution and their potential risks on land degradation, the application of this restriction still limited. Consequently, to ensure agricultural development sustainably and to overcome the reduction of yield in terms of quantity and quality related to the poor irrigation water quality in the light of the complex soil function is multiple absorptions, storage, release, filtration, and transport, the key factors involving in the agrosystems functioning should be carefully examined.

The impact of water quality on the soil's various functions is variable and requires more detailed evaluation based on soil hydrodynamic proprieties, nexus soil-plant-atmosphere, more attention has been paid to optimize economic investment. Water scarcity in terms of availability and suitability is constraining agricultural sustainable production especially in hot dry areas where the agricultural development relies exclusively on groundwater resources exploitation. The irrigation with these generally low renewable highly mineralized resources leads to increasing ecological disturbance and limits the selection of the cultivated crops depending on its tolerance to environmental conditions. Thus, management strategies of the agricultural sector should be with taking into consideration the perpetual changes of irrigation water quality related to geographical location, how water has been extracted and used, rainfall intensity, and subsequent aquifer recharge (Zaman et al. 2018). Consequently, a large spectrum of classification tools has been developed varying from simple classification based on analytical results, calculated ionic ratios, graphical representation, and calculated index, and use of statistical approaches (USSL 1954; Andry and Suassuna 1995; Wiclox 1955; Shalhevet and Kamburov 1976; Ayers and Westcot 1991; Glover 1996; Maia 1996; Ganfopadhyay et al. 2001; Shahid 2004; Singh et al. 2005; Stigter et al. 2006; Maia et al. 2012; Zaman et al. 2018).

Undoubtedly, the succession of these techniques highlights that each classification has a certain degree of accuracy while none has proven entirely satisfactory this partial classification may lead to partial evaluation of irrigation water impacts. Indeed, these techniques are developed to be used under the average condition concerning soil characterization (texture, infiltration,), drainage (irrigation technique), climate conditions, crop tolerance (Wilcox 1955). Therefore, a large deviation of the average circumstances of one or more factors may make the classification unavailable and unsafe. For this reason, Merireles et al. (2010) indicated that the generalization of the developed technique is not acceptable due to the special characterization of each water system. Zhang (2017) has modified USSL (1954) diagram has discussed the conditional use of low quality relative to six major key aspects namely: gypsum content, soil characterization, effective rainfall water table level, type of crops, gypsum conditions while farming practices and management aspects have not been considered. Furthermore, a subsequent review of the maximum acceptable limits of different investigated elements is required along with the evolution of water use efficiency and the variation of ecological factors. Consequently, a new classification approach allowing an interpretation for water characterization in association with different environmental conditions and anthropogenic-related activities is required. The proposed classification scheme must take into consideration the effectiveness of irrigation water on plant-soil characteristics.

Since agricultural resilience to degradation issues is of increasing interest for all the stakeholders and decision-makers to achieve greater yield per unit area and to optimize the use of natural resources, the present paper introduces a comprehensive classification based on giving, often, a general unidirectional field development, the developed classification aims to table a way of facilitation to overcome the limits of the currently used approaches or rather said framework conditions.

Thus, the present study was conducted to present a new classification tool and model the causality links between water quality, soil proprieties, farming practices, climate conditions and different management variables the developed charts give more accurate classification concerning multiple natural factors and artificial neural network influence.

The proposed charts present a revised version of the commonly used classification diagrams which present a narrow spectrum of parameter variation Wilcox (1954), Riverside (1955), USSL (1954), FAO (1998), Styufzand (1986) diagrams concerning the heterogeneity of the collected data relative to the various influencing factors. These revised versions are more sensitive to irrigation water features by irrigated methods, management practices as effective charts to reduce the risks and increase water and soil use efficiency.

2. STUDY AREA

The development of assessment tools for ecosystem classification or risk evaluation requires accurate examination of any impact category, to have a unique translation in scientific conditions on a global scale. Otherwise, this classification should comply with the following aspects, the worldwide application acceptance by the supervision committee, available data from different countries, and the examination of the causality links between the natural ecosystem and the potential risk constraining healthy functioning.

However, generally, the used standards and the local available conditions are not available. The lack of georeferenced maps and online statistical descriptive resources for a large part of Tunisia and North Africa regions male it difficult to complete the analysis of natural areas proprieties with the hierarchical influencing factors. Thus, as a preliminary step for introducing the newest classification diagram, the developed approaches have been validated by specific studied areas located in SW Tunisia.

The choice of the region of interest of (Kebili and Tozeurregions) is justified by the importance of the agricultural sector in supporting the socio-economic pressure of the area and in inhibiting further land degradation and reinforcing the economic dimension of the natural agrosystems.

This is a region devoted to date palm production, greenhouse development with a less percentage. The total irrigated land covers more than 50,000 ha, with an annual production exceeding 250, 000 tons of date palm. The agricultural sector participates with more than 60 % of the total employment of the area (CRDA 2018). The climate is characterized by hot dry conditions with rainfall exceeding occasionally 100 mm and a temperature of 46 to 50°C during summer. The evapotranspiration is high as more than 2500 mm. the irrigation of oasis and greenhouses rely principally on groundwater resources namely CI and CT low renewable waters (Hajji et al . 2012; Hamed et al. 2014, 2018).

The soil in the study area varies from gypsiferous soil, raw mineral soil, skeletal soil, and holomorphic soil with a maximum percentage of gypsum soil. A frequent gypsum impermeable crust is generally observed and about 1.25ha/yr is lost to infertility and loss of permeability salinization issues. The abandonment of the developed oasis is observed on averagely average after 10 years from the first irrigation (Hamed 2015; Mokadem et al. 2016, 2018; Dhaouadi et al. 2017).

During the last decades, numerous environmental issues with important economic constraints have been registered and discussed amplified by the climate challenges. Thus, the main purpose of this paper is widely applied for the region to develop a tree structure to make it possible to cover the complex network and represent consequently various dimensions in a meaningful way.

3. NEW CLASSIFICATION DIAGRAMS

3.1. Texture and salinization issues

The most important item of a review or introduction of new approaches and techniques might be the use of a hierarchical structure, simplified by a tree structure for which the classification is well qualified since the classification of subcategories into super-ordinate categories by means implies an order of value while the importance of the classification is obtained when considered in its totality. For irrigation water quality issues, in most agro-based regions, salinization represents the main issues threatening land productivity. Thus, water suitability for irrigation purposes is generally evaluated according to EC and TDS content.

Taking the example of USSL (1954), Styufzand (1986), FAO (2007)…. and different other classifications that consider the water EC and TDS function of the cultivated crops, the potential effects of this dynamic problem and its evolution largely depends on the soil texture and structure distribution at the surface as well as along soil profile. Thus, if the goal is to provide a comprehensive classification for many interdisciplinary purposes, the adequacy of the used resources for irrigation should be evaluated in light of several factors to ensure a generally valid understanding. Undoubtedly, the soil fertility and pores sealing risks depend on the grain size of soil material as well as their arrangement which will largely impact water holding capacity and cement gypsum crusts development, consequently, soil nutritional characteristics and infiltration issues. Thus, the proposed chart represents four axes describing the most influential factors governing soil productivity related to soil salinity (EC), soil alkalinity (SAR), soil permeability (clay and sand)

Although fine texture soils have high cation exchange and water holding capacity leading to leaching of nutrients as well as drought stress are the main problems of coarse texture soils (Bradly 2008)Sandy soils can withstand high salinity irrigation water because more dissolved salts will be removed from the root zone by leaching.

Previous studies have proven that besides the initial structure of soils during the first years of activities, the productivity of this structure decreases progressively to lead to total abandon.

With higher water salinity and unfavorable climatic conditions, soil texture ranging from sandy loam to clay loam is generally characterized by good internal drainage of irrigation water, that may reduce land productivity loss and promote the manageable progressive accumulation of soluble salts in the root zone (Fig. 1)

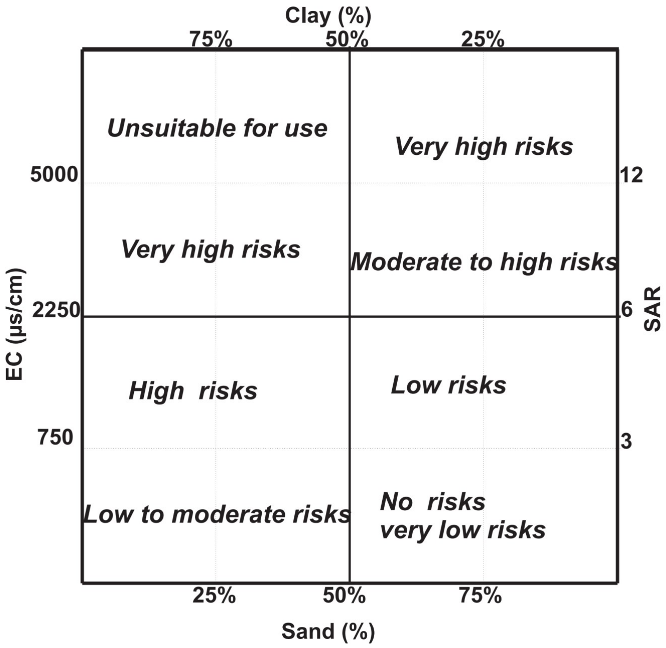

Fig. 1. EC vs. Texture diagram.

The study area represents a spectacular example of an analytical study of different soil types impacted by poor water quality. The continuous use of these waters has induced homogenous outfits dominated by gypsum crust development and progressive loss of infiltration leading to progressive abandon of oasis.

The distribution of soil salinization function of soil characteristics in the studied regions highlights that the EC increases correspondingly with the percentage of clays. Taking the example of oued Tourba, Ain Rebah, Oued Tourba, and Ain Koucha regions where soil salinity decreases with an increasing percentage of coarse sandy soils even though the total sandy fraction increases (Besser et al. 2021). Fine fractions reduce, however, the infiltration of irrigation water and enhance the condensation of deposited salts in continuous gypsum crust after the loss of excess water to evaporation.

The variation of the measured EC is also visible for sandy soil as the physical-chemical physicochemical functional characteristics such as EC, thermal conductivity, are often determined by the external soil surface which gives the partial interpretation.

3.2. Sodicity issues

The second approach is a proposal of alkalinity issues evaluation targets the impacts of excessive Na-content irrigation water. Increasing Na-content in agricultural land impedes sustainable productivity via soil dispersion, and the development of clay platelet and aggregate plug soil pores leading to the progressive reduction of soil permeability. Increasing water salinity will induce clay dispersion swelling related to Na increasing structural breakdown Elevated sodium in the applied water displaying calcium and magnesium from the exchange in the surface layers enabling increased leaching of these cations deeper into the profile) (Hanson et al . 1999).

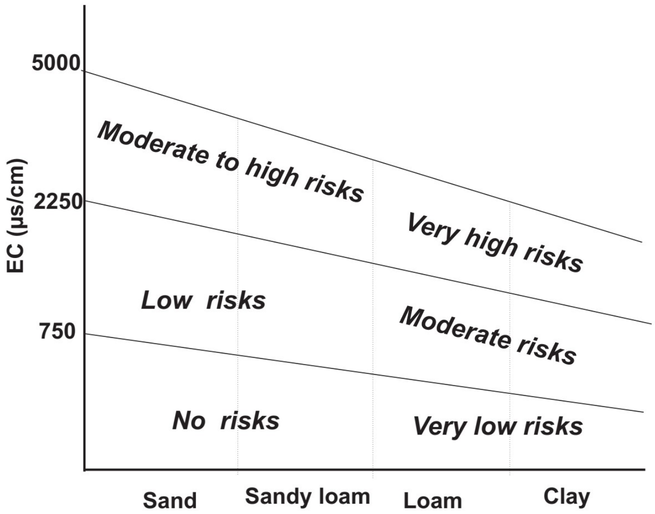

Fig. 2. Alkalinity and salinity classification chart

The likely consequences are more important in clayey soils than in sandy and loamy lands (Fig. 2). Indeed, when soil is repeatedly wetted and dried and clay dispersion occurs it then reforms and solidities into almost current like soil with little or no structure (reduction of infiltration, reduced hydraulic connectivity, and surface crusting) (Hanson et al . 1999).

Unfortunately, previously published classification approaches have generally defined the alkalinity issues concerning the chemical water composition (SAR, EC, ESP, SSP, …). However, field conditions namely fertilization and soil texture and structure are influencing factors that modify greatly the distribution of Na-content and consequently make variable the likely consequences for lateral and vertical trends. Thus, the proposed chart additionally integrates soil proprieties attributes which help to not only possible to detect the respective processing stage of alkalinity challenges but essentially to compare difficult soil fertility evolution regarding their physic-chemical proprieties concerning irrigation water Na-content. Furthermore, this chart due to the lack of local scale available standards, the classification often limited to international limits, independently of the cultivated crop proprieties is finite at more specific levels while more profound assessment of individual sub-categories (percentage of each texture variation) with increasing Na concentrations is required.

3.3 Permeability issues

Even though the previous works have highlighted the importance of permeability aspects of irrigation water, they have specifically considered the chemical composition of irrigation water as the unique important factor there are more important factors to be considered to maintain or inhibit further loss of permeability, chemical and physical changes related to instantaneous or progressive interaction occurring during irrigation or infiltration or due to the frequent use or inappropriate technical assistance or engineering problems require more interactive classification tool. Thus, to a certain degree of effectiveness the previously used criteria and the definition used to assess permeability challenges imply other field conditions and different water criteria as being essential to confirm the degree of the risk to raise the process than that suitability question to a characterization that may explain more unambiguous processing features. Thus, the most expedient method of creating a new classification system is to involve climate conditions, water quality, and soil characteristics as the risks of permeability cannot be studied as independent issues but they are defined by dependent constraints varying according to their intended causality links their monitoring and their perpetually variable influence. Irrigated soils are subject to sequential periods of rapid wetting followed by drying resulting in low aggregate stability (Caron et al. 1992; Rasiah et al. 1992) resulting in the release of colloidal material and the collapse of soil pores (Levy and Miller 1997). However, the quality of the irrigation water applied will also affect the soil chemical proprieties which influence soil dispersion and aggregate breakdown surface sealing and crust formation and changes in the information function (Shainberg and Letey 1994). The repeated application of irrigation water was visually found to produce an applied surface layer approximately 5 cm thick. This layer ex cited characteristic signs of hard setting behavior associated with soils of similar texture (Mullins et al. 1990) including a collapse of some or all of the aggregated structure with setting and a Harding without restructuring drying. The distribution of the particles along the soil profile controls largely the reduction of aeration and permeability efficiency (Fig. 3). In this context, Alperovitch et al. (1985) found that a decrease in hydraulic conductivity on soils with high exchangeable sodium and electrolyte concentrations was primarily associated with an increase in clay tactoid swelling.

In the studied area, permeability loss issues define the complex nexus of soil-water-climate (Besser et al. 2021) amplified by mismanagement of anthropogenic activities. The permeability constraints are commonly observed issues in different areas of Tunisia (Hamed et al. 2014; Mokadem et al. 2016; Ayadi et al. 2018; Hamad et al. 2018).

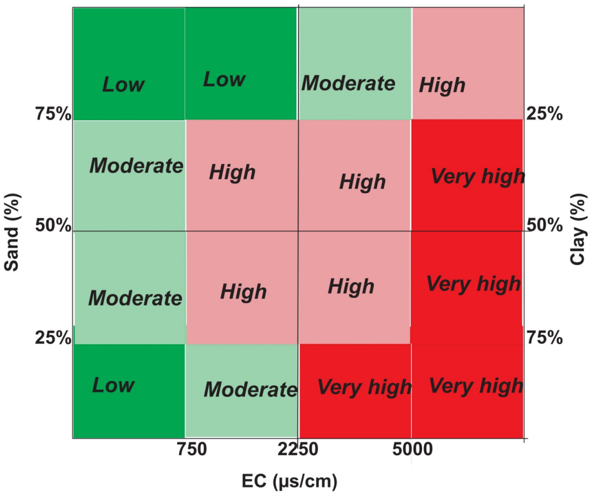

Fig. 3. Permeability diagram.

3.4. Farming practices and management efforts

Besides the evolution of the characteristics of natural resources, the physic-chemical effects of the applied irrigation water quality associated with the variable soil characteristics depend on the frequency and the cycles of the wet-dry period and the farming practices to optimize crop intake of water and nutrients (Fig. 4). Investment in irrigation equipment and water-saving plans are required to reduce and remediate negative impacts on crop yield. However, the values of the achieved and the implemented management plans show considerable variability depending on local conditions namely soil characteristics and water quality evolution. Farming practices represent the driving force of this spatial and temporal variability.

Dhaouadi et al. (2020), Abderrasul et al. (2000), and Muaini et al. (2017) indicated that irrigation techniques and engineering process of irrigation scheme is of crucial importance to reduce soil permeability loss, the query about the loss of productivity is consequently, a result from nexus; natural conditions-farming practices-control effectiveness. The choice of irrigation scheme from flooding old technique, to gravity method to more localized techniques such as drip or bubbler (Dhaouaid et al. 2017). Irrigation scheduling (hours/n frequency/ seasonal variability) and irrigation technique (drip, gravity model- flooding, bubbler…) are closely related to irrigation water availability first and soil physic-chemical proprieties second. Additionally, fertilizer application techniques, the applied amount, and the drainage-runoff system represent two huge issues constraining productive agricultural development. The repercussions of these two factors are visible often via cumulative long-term impacts especially for hot-dry areas where the quasi-constant climate conditions between the summer and winter period do not make different irrigation characterization.

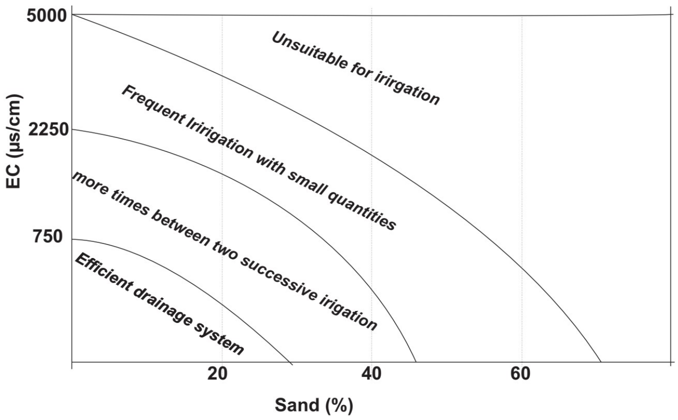

Fig. 4. Permeability diagram

Clay soils can hold more water and are slower to drain than coarse-textured soils smaller particles can pack closely to gather block the spaces between particles and prevent water from passing through while sand particles are larger and therefore have larger pore spaces and prevent water to pass through. Therefore, the effect of water quality for irrigation purposes requires a classification not only based on the chemical components of the analyzed water but principally on the cumulative impacts and (or) the combination of irrigation water, agricultural land proprieties, and management practices namely irrigation techniques, drainage systems, and irrigation scheduling which control directly and (or) indirectly the density of the seal formation, the water loggingwaterlogging issues, the challenging problem in bulk density change and the stable aggregate percentage.

In the study area, different practices are used. Thus, the evaluation of the sued approaches based on the collected data indicates that the irrigation system is the first factor to be considered followed by irrigation water quality and fertilizer manure application concerning different soil textures. The used types of cultivation and the frequency of cultivation are two other main constraints. The indigenous knowledge of farmers and the related application represent for this study a huge challenge for a reliable examination and comparison of the collected data. (Fig. 5)

4. Conclusions

The new approaches developed in this study for assessing the environmental impact of irrigation water quality were examined and validated on the local scale of the studied area of southwestern Tunisia. The approach adds an innovative contribution since the previous classification and methodological studies have principally relied on the salinization and issue a limited number of risk criteria principally related to the chemical water composition independently from field conditions and engineering process. Four biological, ecological, hydrochemical, and pedological variables belonging to the proprieties of field analytical outputs and pressure frameworks were selected for the introduced modified version of the classification tools. The new proposed classification chart represents the first step to an environmental correlation model built for farm-scale to respond to evaluate will more precision the variation of the irrigation water suitability and consequently the potential impacts at small scale.

This study is the first to be aware of the adaptation at the international level to include large divisions of the terrestrial ecological regions (eco-regions). The simultaneous examination of field conditions and analytical results coupled with risks is a major advantage for gathering information that can be helpful when applied to the decision-making of land management for sustainable agricultural development.

Fig. 5. Farming practices and institutional management process

Although the proposed diagrams for risk prediction take into account the interactive and cumulative links between different influencing factors more precise knowledge is required to adjust and integrate more indicators. The proposed approach is a simplified approach that should be calibrated and improved when applied to specific case studies. The introduced scheme could be complemented with specific factors related to farming practices and variable soil proprieties along with depth and human activities. It may be extended through it seems to be a long-term task given its magnitude and difficulty will be considered partially examined. Further classifications and evaluations are required to integrate climate conditions. These easy tools developed for preliminary assessment are available for large-scale development and territorial planning adopted to farm-scale and may be easily diffused to different responsibilities for sustainable irrigation agriculture.

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