Sustainable Indicators in Arid Region: Case Study – Egypt

Elsayed Said Mohamed, Mohamed Abu-Hashim, and Abdel-Aziz A. Belal

Contents

Abstract Increasing of population and scarcity of water resources in arid and semiarid countries are one of the major obstacles to sustain agricultural development. When we are talking about Egypt as a case study, there are many reasons that impede sustainable development. These reasons could vary according to spatial distribution. That the urban sprawl is considered one of the most serious factor that impedes the sustainable development in the Nile valley and delta. On the other hand, the northern regions of the Nile Delta face another critical situation that affects the agricultural development and maintaining its development. The northern part suffers from land degradation due to high salinity levels besides rising of the groundwater table. Therefore, this chapter focuses on the assessment of sustainable agricultural development according to several axes. It discusses land productivity, security, protection, validity, and acceptability as well as economic and social factors. Remote sensing techniques and GIS as new trends have been reviewed

---

E. S. Mohamed (✉) and A. A. Belal
National Authority for Remote Sensing and Space Sciences, Cairo, Egypt
e-mail: salama55@mail.ru

M. Abu-Hashim
Soil Science Department, Faculty of Agriculture, Zagazig University, Zagazig, Egypt

A. M. Negm and M. Abu-hashim (eds.), *Sustainability of Agricultural Environment in Egypt: Part I - Soil-Water-Food Nexus*, Hdb Env Chem (2019) 76: 273–294,
DOI 10.1007/698_2018_243,
Published online: 27 April 2018

and considered in this chapter to assess and mapping sustainability degree. Three different methods were reviewed throughout this chapter, and these methods depend on integrating environment, economy, and society factors.

Keywords Remote sensing, Spatial distribution, Urban sprawl, Water scarcity

1 Introduction

Sustainable development is defined as “development that meets the needs of the present without compromising the ability of the future generations to meet their own needs” [1]. Egyptian territory area about 1 million km^2 is made up as follows: Nile valley and delta about 4% of the total; Eastern desert area about 22%; Western desert area about 68%; and Sinai Peninsula area about 6%. The share of Nile water in Egypt is 55.5 billion m^3 $year^{-1}$, representing 76.7% of the country’s available water resources; desalinated seawater comprises only 0.08%. Total groundwater plus treated groundwater is 20.65 billion m^3 $year^{-1}$ (28% of available water resources), but it cannot be added to Egypt’s share of water as it is a reused source [2]. Sustainable agriculture is increasingly viewed as a long-term goal that seeks to overcome problems and constraints that confront the economic viability, environmental soundness, and social acceptance of agricultural production system both in the USA and worldwide. While there are many definitions of sustainable agriculture, most of them espouse the same elements of productivity, profitability, conservation, health, safety, and the environment, that differ only in the degree of emphasis. There is a general agreement that sustainable development includes environmental, economic, and social dimensions [3]. Sustainability indicators characterizing these three dimensions are generally used to bridge the gaps between theoretical concepts and actual measures [4, 5].

Sustainable agriculture is farming systems that are maintaining their productivity and benefit to society indefinitely [6]. Despite the diversity in conceptualizing sustainable agriculture, there is a consensus on three basic features of sustainable agriculture: (1) maintenance of environmental quality, (2) stable plant and animal productivity, and (3) social acceptability. A sustainable farming system is productive and safe and conserves the natural resource base. Moreover, there are several problems faced by sustainable development such as loss of soil productivity from excessive erosion/intensive cultivation and associated plant nutrient loss/depletion; surface and groundwater pollution from pesticides, fertilizers, and sediments; impending shortages of nonrenewable resources; and low farm income due to low commodity prices and high production costs [7]. Sustainable Land Management (SLM) in agriculture is a very complex and challenging concept that encompasses biophysical, socioeconomic, and environmental concerns that must be viewed in an integrated manner. An international Framework for Evaluating Sustainable Land Management (FESLM) was developed to provide a base for addressing these issues comprehensively. SLM combines technologies, policies, and activities aimed at integrating socioeconomic principles with environmental concerns so as to simultaneously satisfy the five pillars of SLM. Those pillars are as follows: to protect the potential of natural resources and prevent degradation of soil and water quality (protection), to reduce the level of production risk (security), to be economically viable (viability), to maintain the production services (productivity), and to be acceptable (acceptability). The information and data obtained from the studied area have been analyzed according to the FELSM methodology to develop SLM indicators that address the five pillars of the FESLM. Knowledge from the farmers themselves through 58 questionnaires held with them in suite and many publications concerning the investigated area have been acquainted.

2 Obstacles to Sustainable Development

Sustainable development in arid and semiarid regions faces many constraints. These constraints vary according to geographical location, socioeconomic conditions, and climate. This section will review the main obstacles as follows:

- High population growth and pressure; agriculture production has to be increased by 70% within 2050 in order to face the population growth and changing diets [8]. Agriculture will furthermore need to minimize the emissions of greenhouse gases, pesticides, and plant nutrients like nitrogen and phosphorous to the environment. However, this production increase will have to be achieved in a way that preserves the environment and reduces the vulnerability of agriculture to climate change.
- Dependency of livelihoods on agriculture; with 65–70% of the population depending directly on rain-fed agriculture and natural resources. Industry and the service sector also depend heavily on land management [9].
- Climate change: these include higher temperatures, water scarcity, unpredictable precipitation, higher rainfall intensities, and environmental stresses [10]. Since the industrial revolution has already deeply impacted ecosystems, the main concept from the climate change story is that public do not recognize and trust scientists until it really hurts. In addition, all society issues cannot be prepared using the old and painkiller approaches because all issues are now huge, linked, global, and fast-developing. Thus, actual society structures are probably outdated. Here, agronomists are the most advanced scientists to solve social issues because they master the study of complex systems, from the molecule to the global scale. Now, more than ever, agriculture is a central point to which all social issues are bound; indeed, humans eat food [6].
- Land degradation has negatively affected the state and the management of the natural resources (soil, water, and plants). Land degradation occurs in different forms on various land-use types:

For cropland: soil erosion by water and wind forces; water degradation mainly caused by increased surface runoff (polluting surface water) and changing water availability as well as high evaporation leading to aridification, chemical degradation – mainly fertility decline – due to nutrient mining, and salinization; soil physical degradation due to crusting, sealing, and compaction. That leads to insufficient vegetation cover, decline of local crop varieties, and mixed cropping systems.

For grazing land: biological degradation with loss of vegetation cover and valuable species; the increase of alien and "undesirable" species. The consequences in terms of soil physical degradation, water runoff, and erosion are widespread and severe. Low productivity and ecosystem services from degraded grazing lands are widespread and a major challenge to SLM http://www.fao.org/docrep/014/i1861e/i1861e01.pdf.

3 History of Sustainability

Sustainable development is a major concern of all nations given the need to preserve the global environment. Since the Stockholm Declaration, signed in 1972, there have been many initiatives towards global environment protection [11]. In Den Haag, some 24 leading countries have signed a declaration to harness global climate change. Moreover, in June 1992 the United Nation World Summit in Rio de Janeiro produced piles of documents pledging to sustain the global environment [12]. Also, many governments including the federal and provincial governments in Canada as well as the Consultative Group on International Agricultural Research (CGIAR) have indicated that SLM is a matter of priority in the coming years. Some international agencies in cooperation with national research institutions in Canada, the USA, and others have collaborated to develop the principles and recommended procedures for a Framework for Evaluating Sustainable Land Management (FESLM), and to host two international workshops. The first was in Chiang Rai, Thailand, in 1991, which resulted in the formation of an International Working Group (IWG) to further the development of the FESLM, and the second was in Lethbridge, Canada, in 1993, which focused on the indicators to be used for evaluation of sustainability. Results from this work were reported at a symposium at Acapulco, Mexico, as part of the 15th World Congress of Soil Science. Recently in 1997, the Second World Summit was held in New York to evaluate the implementation of all commitments and of the agenda formulated in Rio de Janeiro and to draw up an action plan to sustain our planet for the next century, and the more distant future [13].

4 Methods Used to Assess Sustainable Land Management

Several methods and indicators have been proposed to assess sustainability condition during last three decades, and in this section we review three frameworks:

1. Liu and Zhang [14] proposed a methodological framework for assessing the sustainability level of main agricultural regions in China on regional and county levels. Four sustainable categories were distinguished: environmental, social, economic, and comprehensive sustainability. The two distinguished methods for measuring the sustainability were:

   (a) The balanced performance method that measures balanced performance among different aspects of sustainability; a minimum value method was used according to the following equation:

   $$\mathrm{CI}_c = \operatorname*{Min}_{j=1}^{n} \; v_j\left(x_j\right)$$

   and

   (b) The aggregate achievement method that measures aggregate achievement of all aspects. This method aims at aggregated using multi-attribute value theory, a compensatory method, because of its ability to analyze many dimensional conditions and allow the conduction of assessments [15]. The value function of the additive model was used because of its simplicity.

   $$\mathrm{CI}_c = \sum_{j=1}^{n} w_j v_j\left(x_j\right)$$

   where CI_c is the comprehensive sustainability of county c, w_j is the weight of the sustainability indicator j estimated by Analytic Hierarchy Process (AHP) that was employed to determine factor weight, n is the number of indicators, and v_j (x_j) transforms individual indicator x_j into commensurable units between 0 and 1.

   Spatial variation maps of sustainability across countries were produced using a geographic information system (GIS) for generating, displaying, and spatially analyzing information for the measurement of sustainability. Moreover, the author classified the degree of sustainability into five ratings (very low, low, medium, high, and very high). The limiting factors in each region were identified. The same author identified 14 indicators suitable for assessing sustainability framework at the county level. For each indicator, concise definitions, methods of calculation, and indicator type were shown in Table 1.
2. Cornelissen [16] proposed a novel approach to quantify agricultural sustainability using fuzzy set theory. This approach aims at interpreted as to what extent agricultural production systems are able to meet the joint demands, where it considered the joint economic, ecological, and societal perspectives on

Table 1 A novel approach to quantify agricultural sustainability

Dimension	Implication	Indicator	Indicator definition	Indicator type	Weight
Environmental	Land quality index	Shares of top quality land in total	Shares of first- and second-grade land in total land (%)	Positive	0.23
Sustainability		Land limitation level	Shares of above third-grade limited land in total land (%)	Negative	0.25
	Resource carrying index	Cropland per capita	Cropland per capita (ha per person)	Positive	0.15
		Water resource stress index	$C = K X\sqrt{(P X/W)}$ $K = \begin{cases} 1.0 & R \le 200 \\ 1.0 - \frac{0.1 \times (R-200)}{200} & 200 < R \le 400 \\ 0.9 - \frac{0.2 \times (R-400)}{400} & 400 < R \le 800 \\ 0.7 - \frac{0.2 \times (R-800)}{800} & 800 < R \le 1600 \\ 0.5 & R > 1600 \end{cases}$ where p indicates the population ($\times 10^4$ person) A indicates the irrigation area ($\times 10^3$ ha) W represents the total water resources ($\times 10^8$ m^3) K is the coefficient related to rainfall, and R is rainfall (mm)		
	Ecological risk index	Land degradation level	Shares of degraded land due to erosion, salinization, and desertification in total land (%)	Negative	0.12
		Pesticide usage	Pesticide consumption per hectare of cropland (km per ha)	Negative	0.07
Economic	Intensity of land management	Chemical fertilizer consumption	Chemical fertilizer consumption per hectare of cropland (km per ha)	Double meaning	0.25
Sustainability		Effective irrigation rate	Shares of irrigated land in total cropland (%)	Positive	0.31
		Degree of agricultural machinery inputs	Total horsepower of agricultural machinery per hectare of cropland (kw per ha)	Positive	0.19
		Financial investments in agriculture	Agricultural financial investments per hectare of cropland (per person)	Positive	0.13

	Economic benefit	Gross output value of farming	Gross output value of farming per hectare of cropland per person	Positive	0.12
Social	Social prosperity	Gross Domestic Product (GDP) per capita	Gross Domestic Product (GDP) per capita	Positive	0.33
Sustainability	Food security	Grain yield per capita	Grain yield per capita (kilograms per person)	Positive	0.41
	Social instability	Income gap between urban and rural population	Per capita annual disposable income of urban households/per capita annual net income of rural households	Negative	0.26
Environmental	Land quality index	Shares of top quality land in total	Shares of first- and second-grade land in total land (%)	Positive	0.23
Sustainability		Land limitation level	Shares of above third-grade limited land in total land (%)	Negative	0.25
	Resource carrying index	Cropland per capita	Cropland per capita (ha per person)	Positive	0.15
		Water resource stress index	$C = K X \sqrt{(P X / W)}$ $K = \begin{cases} 1.0 & R \leq 200 \\ 1.0 - \frac{0.1 \times (R - 200)}{200} & 200 < R \leq 400 \\ 0.9 - \frac{0.2 \times (R - 400)}{400} & 400 < R \leq 800 \\ 0.7 - \frac{0.2 \times (R - 800)}{800} & 800 < R \leq 1600 \\ 0.5 & R > 1600 \end{cases}$ where p indicates the population ($\times 10^4$ person) A indicates the irrigation area ($\times 10^3$ ha) W represents the total water resources ($\times 10^8$ m^3) K is the coefficient related to rainfall, and R is rainfall (mm)		
	Ecological risk index	Land degradation level	Shares of degraded land due to erosion, salinization, and desertification in total land (%)	Negative	0.12
		Pesticide usage	Pesticide consumption per hectare of cropland (km per ha)	Negative	0.07
Economic	Intensity of land	Chemical fertilizer consumption	Chemical fertilizer consumption per hectare of cropland (km per ha)	Double meaning	0.25
Sustainability	Management	Effective irrigation rate	Shares of irrigated land in total cropland (%)	Positive	0.31

(continued)

Table 1 (continued)

Dimension	Implication	Indicator	Indicator definition	Indicator type	Weight
		Degree of agricultural machinery inputs	Total horsepower of agricultural machinery per hectare of cropland (kw per ha)	Positive	0.19
		Financial investments in agriculture	Agricultural financial investments per hectare of cropland (per person)	Positive	0.13
	Economic benefit	Gross output value of farming	Gross output value of farming per hectare of cropland per person	Positive	0.12
Social	Social prosperity	Gross Domestic Product (GDP) per capita	Gross Domestic Product (GDP) per capita	Positive	0.33
Sustainability	Food security	Grain yield per capita	Grain yield per capita (kg per person)	Positive	0.41
	Social instability	Income gap between urban and rural population	Per capita annual disposable income of urban households/per capita annual net income of rural households	Negative	0.26

agricultural production systems. Since agricultural sustainability is approximated by a selection of sustainability variables, the acceptability of achievements should be determined for every selected sustainability variable. Such a degree of acceptability can be determined using fuzzy set theory [17, 18]. Agricultural sustainability should, therefore, not aim at designing agricultural production systems that last forever in a definite form but monitor the continuous process of adapting agricultural production systems to the specific economic, ecological, and societal systems they are embedded in. Considering the necessary selection of a limited number of sustainability variables, and as a result of the mutually emerging trade-offs, it is impossible to determine indisputably whether an agricultural production system is sustainable or unsustainable. Applying conventional, two-valued logic (e.g., sustainable-or-unsustainable type decisions), therefore, comes to an unsatisfactory conclusion [19–21]. Fuzziness describes event ambiguity: it measures the degree to which an event occurs [22]. Fuzziness, therefore, relates to multivalued logic [19], e.g., all intermediate situations between sustainable and unsustainable are possible. This means that agricultural production systems can be assessed as partially sustainable.

3. This method depends on three steps: sustainability variables, membership functions, and combining degrees of acceptability. The first step seeks to quantify agricultural sustainability to determine which site-specific sustainability variables are taken into account. These sustainability variables can be roughly classified into three clusters, corresponding to the three perspectives on agricultural production. Smyth and Dumanski [23] proposed an FESLM. The FESLM, based on logical pathway analyses, provides a systematic procedure for identification and development of indicators and thresholds of sustainability. The FESLM was developed by an IWG as a recommended procedure by which sustainability of current and alternative land-use systems could be assessed. The FESLM is an extension of the framework for land evaluation (Food and Agriculture Organization of the United Nations [24]), except that evaluations are based on indicators of performance overtime, rather than land suitability. An assessment of sustainability is achieved by comparing the performance of a given land use with the objectives of the five pillars of SLM: *productivity*, *security*, *protection*, *viability*, and *acceptability* (Fig. 1). A classification for sustainability is proposed, and plans for future development of the FESLM are described.

The classes are a measure of the evaluator's confidence in the stability of factors affecting each system. The actual time limits (Table 2) are intended as a basis for further investigation.

The universality of FESLM allows for the development of a generic decision support system (DSS) which can be customized for local application by using indicators and criteria of local importance. The SLM indicators table provides the threshold, and their quantitative and qualitative ratings. Their score and ranks have been assigned according to the type of indicator (strategic, cumulative, or suggestive). Based on the knowledge-base, the rule-base for SLM indicators has been established. The trend of SLM indicators over time, in combination with their

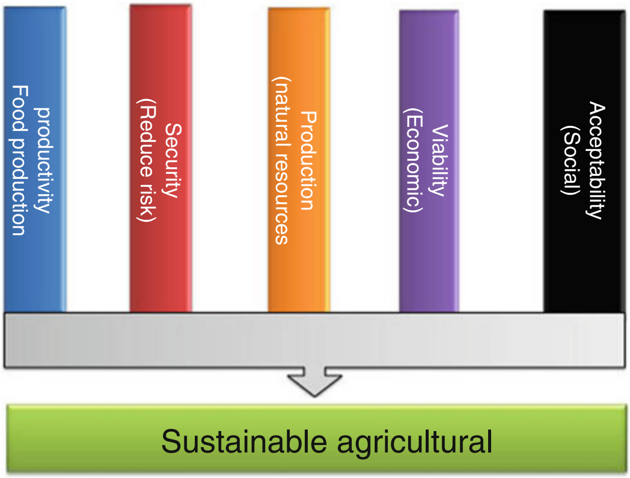

Fig. 1 Five pillars of sustainable agriculture

Table 2 Classes of sustainability proposed in the FESLM (source: [23])

	Classes	Confidence limits (year)
Sustainable	1. Sustainable in the long term	>25
	2. Sustainable in the medium term	15–25
	3. Sustainable in the short term	7–15
Unsustainable	1. Slightly unstable	5–7
	2. Moderately unstable	2–5
	3. Highly unstable	<2

threshold values, helps the evaluation of the sustainability of land management practices. The knowledge-base and rule-base act as the backbone of the DSS-SLM. The inference engine helps in processing the knowledge-base and rule-base of SLM indicators. Raise et al. [25] had developed the SLM indicators under the FESLM framework by conducting three case studies in Indonesia, Thailand, and Vietnam. In addition, they used the SLM indicators by developing an expert system based DSS which provides an opportunity to test and operationalize the FESLM concept for practical use. The same author's integration of many subsystems, including data bases, GIS, analytical tools, expert systems, simulations, and a user interface. To ensure proper integration, all software subsystems must follow a unified framework and standard. To make any system extendible and easily modifiable, the code should be modular and consistently commented, indented, and structured [26]. A schematic of the international board for soil research and management (IBSRAM) DSS-SLM under development is given in Fig. 2 (Table 3).

The indicators of SLM were developed along the five pillars of FESLM [25] and these indicators were modified and adapted for Egyptian condition by El-Nahry [28].

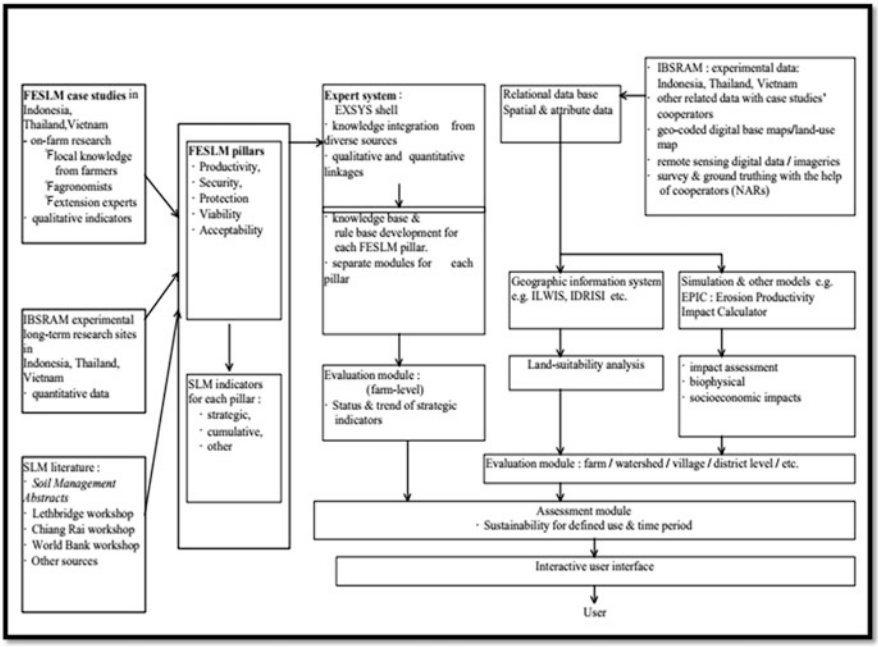

Fig. 2 Schematic representation of the international board for soil research and management (IBSRAM) DSS-SLM (source [25])

Table 3 Sustainability index [27]

Values	Land-use/management status	Class
0.6 to 1	Meet the sustainability requirements	1
0.3 to <0.6	Marginal but above the threshold of sustainability	2
0.1 to >0.3	Marginal but below the threshold of sustainability	3
0 to <0.1	Do not meet the sustainability requirements	4

Sustainability index has been obtained by multiplication of the five pillar indicators. Obviously, the multiplication results vary between 0 and 1. The closer value to 1 is considered the higher degree of the sustainability Tables 4, 5, 6, 7, and 8.

Many Egyptian authors have used remote sensing and GIS for mapping those five pillars (productivity, security, protection, economic viability, and social acceptability) in different areas in Egypt to estimate their accuracy under the Egyptian situations [27, 29–31].

The obtained multiplication results that reflected the degree of the agriculture sustainability are divided into four sustainability classes:

1. Land management practices meet sustainability requirements (from 1 to 0.6) (Table 3).
2. Land management practices are marginally above the threshold for sustainability (from 0.6 to 0.3).

Table 4 Criteria of productivity indicators: [25]

Indicators	Type[a]	Threshold	Qualitative ranking	Quantitative ranking	Score (*a*)	Rank (*b*)	Value ($a \times b$)
Yield	1	>25% or more Yd. reduction of the average of community	Yd. reduction: High	>25%	10	10	100
			Medium	10–25%	10	5	50
			Low	<10%	10	7	70
Soil color: Organic C	1	<1.2%	High: Dark soil	>1.2% (Yd. red. 0%)	10	7	70
			Medium: Brown soil	1–1.2% (Yd. red. 0–20%)	10	5	50
			Low: Yellowish	<1% (Yd. red. >20%)	10	7	70
Plant growth and leaf color: Soil nutrient N	2	<0.5%	High: Dark green leaves healthy, vigorous growth	>0.5%	7	7	49
			Medium: Color normal, moderate growth	0.2–0.5%	7	5	35
			Low: Yellowish leaves, stunted growth	<0.2	7	7	49
P	2	>15 ppm	High: Growth normal, color normal	>15 ppm	7	7	49
			Medium: Growth normal	8–15 ppm	7	5	35
			Low: Older leaves purple, stunted growth	<8 ppm	7	7	49
K	2	>90 ppm	High: Normal growth	>90 ppm	7	5	35
			Medium: Normal plant growth	60–90 ppm	7	5	35
			Low: Leaves yellowish from tip running along edge, and further expand, older leaves show symptoms first	<60 ppm	7	10	70

[a]Indicator's type and their score: strategic (1) = 10; cumulative (2) = 7; suggestive (3) = 3; relative ranking: 1–10. Value = score × rank

Table 5 Criteria of security indicators: [25]

Indicators	Type[a]	Threshold	Qualitative ranking	Quantitative ranking	Score (a)	Rank (b)	Value ($a \times b$)
Average annual rainfall (amount and period) (ET by penman and Montieth)	1	<1,200 mm, spread over 4/8/2017 months	Low: Yd. red. >25%	<1,200 mm, <4 months	10	10	100
			Normal: Yd. red. 0%	>1,200 to <2,400 mm during 4–8 months	10	7	70
			V. High Yd. red. >25%	>2,400 mm, >8 months	10	10	100
Biomass: (% of crop residue) ploughed back to land	2	<50% of cop residue >3 years continuously	High amount for long time	>50% for >3 years	7	7	49
			High amount for short time	>50% for <3 years	7	5	35
			Low amount for long time	<50% for >3 years	7	5	35
			Low amount for short time	<50% for <3 years	7	5	35
Drought frequency	1	<800 mm RF	No drought: Yd. red. 0–25%	Rainfall >800 mm	10	7	70
		>2 years consecutively	Drought: Yd. red. >50%	Rainfall: <800 mm for >2 years	10	10	100

[a]Indicator's type and their score: strategic (1) = 10; cumulative (2) = 7; suggestive (3) = 3; relative ranking: 1–10. Value = score × rank

3. Land management practices are marginally below the threshold for sustainability (from 0.3 to 0.1).
4. Land management practices do not meet sustainability requirements (<0.1) (Fig. 3).

5 Case Studies in Egypt

There are several studies on sustainable agriculture under Egyptian condition. These studies discussed the sustainability constraints such as salinity and alkalinity, lack of infrastructure, and credit utilization. Nawar [31], Abdel Kawy [29], and Mohamed et al. [30] focused their scope of studies on assessment of sustainability factors for

Table 6 Criteria of protection indicators: [25]

Indicators	Type[a]	Threshold	Qualitative ranking	Quantitative ranking	Score (*a*)	Rank (*b*)	Value ($a \times b$)
Erosion	1	4.5 cm or more during last 7 years	Low: Yd. red. 0–10%	<0.7 cm	10	7	70
			Medium: Yd. red. 10–25%	0.7–4.5 cm	10	5	50
			High: Yd. red. >25%	>4.5 cm	10	10	100
Cropping system and extent of protection	2	Double cropping	With hedge row: High: Double cropping	Extent of protection: 80–100%	7	10	70
			Medium: Mono-cropping		7	7	49
			Without hedge row:	50–80%			
			Medium: Double cropping	50–80%	7	7	49
			Low: Mono-cropping	0–50%	7	5	35

[a]Indicators type and their score: strategic (1) = 10; cumulative (2) = 7; suggestive (3) = 3; relative ranking: 1–10. Value = score × rank

agricultural utilization through integrated biophysical, economic viability, and social acceptability using GIS special model in the different areas in Egypt. Mohamed et al. [30] used FESLM to assess agricultural sustainability conditions in north Sinai region. Moreover, they illustrated that an area about 7% of the northern part of Sinai are marginally below the threshold for sustainability where the sustainability values are ranging between 0.1 and 0.3, while the rest of the area does not meet sustainability requirements where the sustainable values <0.1 (Fig. 4). The same authors suggested some recommendations to improve sustainability condition in north Sinai as follows:

- Improved infrastructure in northern Sinai, which includes roads and canals.
- Use of effective management of soil for water and wind erosion control, based on sensible soil conservation practices.
- Attention to social and economic factors that attract people to this area.
- Education to farmers about sustainable agricultural practices so as to be more familiar with improved sustainable practices that will improve their productivity.
- Use of precision agriculture as much as possible in this region as this technique will maximize agricultural yield.

Table 7 Criteria of economic viability: [25]

Indicators	Type[a]	Threshold	Qualitative ranking	Quantitative ranking	Score (a)	Rank (b)	Value ($a \times b$)
Benefit cost ratio	1	B/C ratio 1.00 or more	High	>1	10	10	100
			Medium	1–0.8	10	7	70
			Low	<0.8	10	5	50
Percentage of off-farm income	2	25% or more	High	>25%	7	7	49
			Medium	10–25%	7	5	35
			Low/none	<10%	7	7	47
Difference between farm gate price and nearest main market price	2	>15%	High	>50%	7	7	49
			Medium	15–50%	7	5	35
			Low	<15%	7	7	49
Availability of farm labor	2	1 + 1 man year	High	>2 man year	7	7	49
			Medium	1–2 man year	7	5	35
			Low	1 man year	7	7	49
Size of farm holding	3	1 ha	High	>1 ha	3	7	21
			Medium	0.5–1 ha	3	3	9
			Low	<0.5 ha	3	5	15
Availability of farm credit	3	50% or more of the demand	High	>50%	3	5	15
			Medium	25–50%	3	3	9
			Low	<25%	3	3	9
Percentage of farm produce sold in market	2	50% or more	High	>50%	7	5	35
			Medium	25–50%	7	3	21
			Low	<25	7	3	21

[a]Indicator's type and their score: strategic (1) = 10; cumulative (2) = 7; suggestive (3) = 3; relative ranking: 1–10. Value = score × rank

- Promotion of greater public awareness of the role of people's participation and people's organizations, especially women's groups, youth, indigenous people, local communities, and small farmers, in sustainable agriculture and rural development.

El-Sharkiya governorate of Egypt was better than Sinai where about 31% of El-Sharkiya territory did meet sustainability requirements with score ≥0.65, and 12.6% of the territory represented marginally above the sustainability threshold. Meanwhile, about 48% of El-Sharkiya governorate did not meet sustainability requirements with index values >0.1 [29] as displayed in Fig. 5. The authors used SLM model. Where, they integrated biophysics and socioeconomic elements approach through biophysics elements (productivity, security, and protection) and socioeconomic aspects (economic viability and social acceptability) for the purpose of combating and tackling sustainability constraints that preclude the agricultural development to reduce them to acceptable levels of mass production endeavors.

Table 8 Criteria of social acceptability indicators: [25]

Indicators	Type	Threshold	Qualitative ranking	Quantitative ranking	Score (*a*)	Rank (*b*)	Value ($a \times b$)
Land tenure	2	Full ownership of land	1. Full ownership		7	7	49
			2. Long-term user rights		7	5	35
			2. No official land title		7	7	49
Support for extension services	3	One extension worker per 100 farms	1. Full extension support		3	7	21
			2. Very low extension support		3	5	15
			3. No extension support		3	7	21
Health and educational facilities in village	3	One school and one health center	1. There are adequate educational and health facilities in the village		3	7	21
			2. There is shortage of educational and health facilities		3	5	15
			3. The are no educational and health facilities		3	7	21
Percentage of subsidy for conservation packages	2	50% subsidy	1. There is sufficient subsidy available	1. 50% or more	7	5	35
			2. There is limited subsidy	2. <50%	7	5	35
			3. There is no subsidy		7	5	35
Training of farmers about soil and water conservation	3	Training once in 3 years	1. There has been sufficient training	1 Once or more in 3 years	3	5	15
			2. There has been no training	2. No training	3	5	15
Availability of agro-input within 5–10 km range	3	Easy access to agro-chemicals and seeds etc.	1. Agro-inputs are available as per requirements		3	5	15
			2. Inputs are available in limited manner		3	5	15
			3. No inputs are available		3	5	15
Village road access to main road	3	Village road has full access to main road	1. Village road has full access to main road	1. 80–100% road ready	3	7	21
			2. Limited access to main road by motor	2. 50–80% road ready	3	5	15
			3. No access to main road by motor	3. <50 road ready	3	5	15

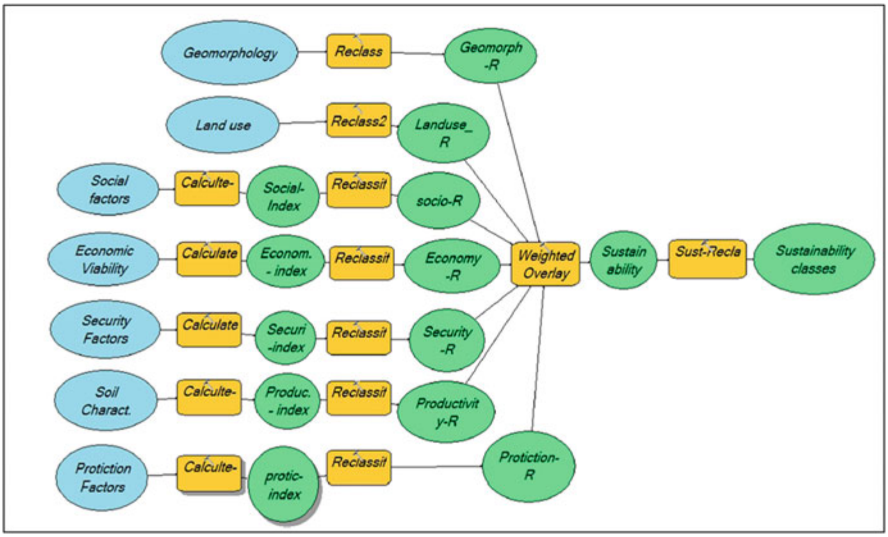

Fig. 3 Sustainable agricultural special model (SASM) (source, [30])

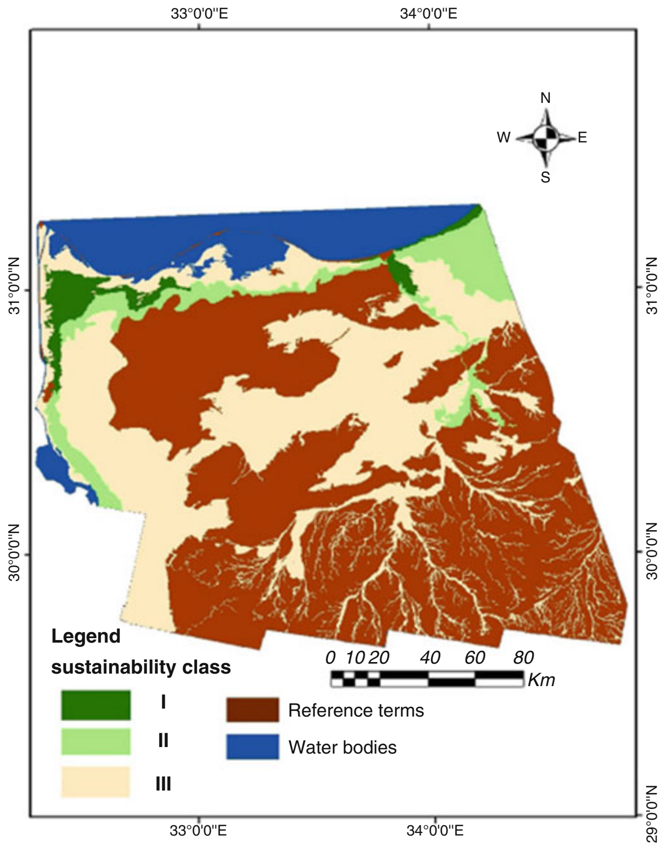

Fig. 4 Sustainability classes in North Sinai

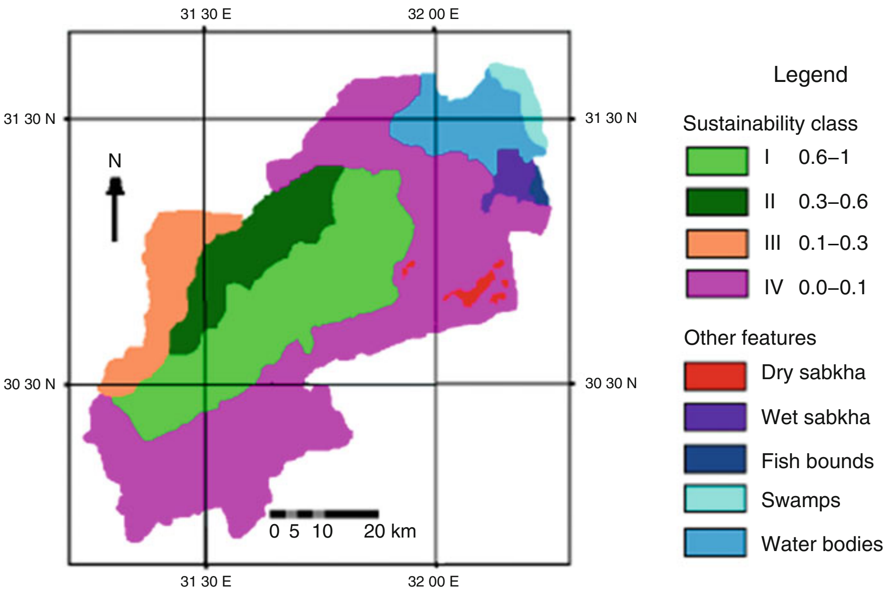

Fig. 5 Sustainability classes in El-Sharkiya governorate (source, [27])

Kafr El-Sheikh Governorate has been classified into two different class types, the first is the lands that are marginally below the requirement of sustainability and the second are those lands that do not meet sustainability requirements [29] as shown in Fig. 6. The sustainability constrains in the studied area are related to the soil productivity, economic viability, and social acceptability.

6 Conclusion

Sustainable agriculture is increasingly viewed as a long-term goal that seeks to overcome problems and constraints that confront the economic viability, environmental soundness, and social acceptance of agricultural production system in Egypt. While there are many definitions of sustainable agriculture, most of them espouse the same elements of productivity, profitability, conservation, health, safety, and the environment. There is a general agreement that sustainable development includes environmental, economic, and social dimensions. SLM combines several technologies, policies, and activities aimed at integrating socioeconomic principles with environmental concerns to simultaneously satisfy the five pillars of SLM. In conclusion, the five pillars of SLM could be used to protect the potential of natural resources and prevent degradation of soil and water quality, to reduce the level of

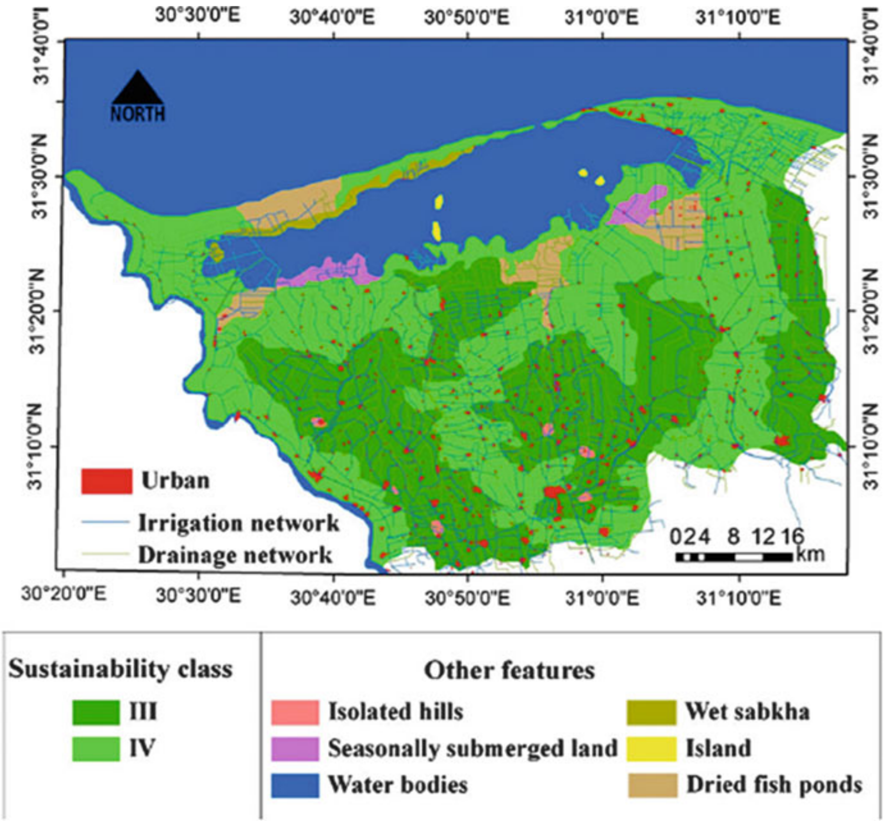

Fig. 6 Sustainability classes in Kafr El-Sheikh governorate (source, [29])

production risk, to be economically viable to maintain the production services, and to be acceptable.

7 Recommendation

The authors recommend that for sustainable agriculture, there is a consensus on several basic features of sustainable agriculture in Egypt that could contribute to 2030 Egyptian sustainability plan: (1) maintenance of environmental quality, (2) stable plant and animal productivity, and (3) social acceptability. In addition, SLM in agriculture is a very complex and challenging from the point of view of enhancing the biophysical, socioeconomic, and environmental concerns that would enhance the land potentiality for sustainable agriculture. The SLM is a good strategy to sustain development to overcome the loss of soil productivity from excessive erosion/ intensive cultivation and associated plant nutrient loss/depletion; surface and groundwater pollution; impending shortages of nonrenewable resources; and low farm income due to low commodity prices and high production costs.

Acknowledgement The authors acknowledges Dr. Mohammad RAIS Senior Principal Scientist, CSIR-NISTADS, Pusa Gate, New Delhi for his support with figures and tables.

References

1. WCED (1987) In: Brundtland GH (ed) Our common future. Report of the World Commission on Environment and Development. Oxford University Press, Oxford
2. CAPMAS, Central Agency for Public Mobilization and Statistics (2009) CAPMAS Egypt in Central Agency for Public Mobilization and Statistics (CAPMAS), Cairo. www.capmas.gov.eg
3. Van Cauwenbergh N, Biala K, Bielders C et al (2007) SAFE – a hierarchical framework for assessing the sustainability of agricultural systems. Agric Ecosyst Environ 120:229–242
4. Bell S, Morse S (2008) Sustainability indicators: measuring the immeasurable? Earthscan, London
5. Gómez-Limón JA, Riesgo L (2009) Alternative approaches to the construction of a comprehensive indicator of agricultural sustainability: an application to irrigated agriculture in the Duero Basin in Spain. J Environ Manag 90:3345–3362
6. Lichtfouse E (2009) Climate change, society issues and sustainable agriculture. In: Lichtfouse E (ed) Climate change, intercropping, pest control and beneficial microorganisms, sustainable agriculture reviews, vol 2. Springer, Dordrecht. https://doi.org/10.1007/978-90-481-27160-1
7. Lockeretz W (1988) Open questions in sustainable agriculture. Am J Altern Agric 3(4):174–181
8. Aune JB (2012) Conventional, organic and conservation agriculture: production and environmental impact. In: Lichtfouse E (ed) Agroecology and strategies for climate change. Sustainable agriculture reviews, vol 8. Springer, Dordrecht, pp 149–165
9. Eswaran H, Almaraz R, van den Berg E, Reich P (1997) An assessment of the soil resources of Africa in relation to productivity. Geoderma 77:1–18
10. IPCC (2007) Climate change 2007 – impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the IPCC. http://www.ipcc.ch/ipccreports/ar4-wg2.htm
11. Sohn LB (1973) The Stockholm declaration on the human environment. Harv Int Law J 14:423
12. Mann H (1992) The Rio declaration. In: Proceedings of the annual meeting (American Society of International Law), The American Society of International Law, Washington, pp 405–414
13. Sand PH (2007) The evolution of international environmental law. In: Bodansky D, Brunnée J, Hey E (eds) The Oxford handbook of international environmental law, vol 29. Oxford University Press, Oxford
14. Liu F, Zhang H (2013) Novel methods to assess environmental, economic, and social sustainability of main agricultural regions in China. Agron Sustain Dev 33:621–633
15. Dantsis T, Douma C, Giourga C et al (2010) A methodological approach to assess and compare the sustainability level of agricultural plant production systems. Ecol Indic 10:256–263
16. Cornelissen AMG (2002) A novel approach to quantify agricultural sustainability using fuzzy set theory. Synergy Matters:49–54
17. Bockstaller C, Girardin P, Van der Werf HMG (1997) Use of agro-ecological indicators for the evaluation of farming systems. Eur J Agron 7:261–270
18. Silvert W (1997) Ecological impact classification with fuzzy sets. Ecol Model 96:1–10
19. Klir GJ, Folger TA (1988) Fuzzy sets, uncertainty, and information. Prentice-Hall, Englewood Cliffs
20. Pedrycz W (1993) Fuzzy control and fuzzy systems. Research Studies Press, Taunton
21. Zimmermann H-J (1996) Fuzzy set theory and its applications. Kluwer Academic, Boston

22. Kosko B (1992) Neural networks and fuzzy systems. Prentice-Hall, Englewood Cliffs
23. Smyth AJ, Dumanski J (1993) FESLM: an international framework for evaluating sustainable land management. A discussion paper. World soil resources report 73. FAO, Rome, 74 pp
24. FAO (1976) A framework for land evaluation. Soils bulletin 32. Food and Agriculture Organization of the United Nations, Rome
25. Raise M, Craaswell ET, Gamada S, Dumanski J (1997) Decision support system for evaluating sustainable land management in sloping lands of Asia. IBSRAM, Bangkok
26. Jacucci G, Foy M, Uhirk C (1996) Developing transportable agricultural decision support system: Part 1. A conceptual framework. Comput Electron Agric 14:291–300
27. Abdel Kawy W, Ali R, Darwish K (2012) Sustainable multivariate analysis for land use management in El-Sharkiya, Egypt. Arab J Geosci. https://doi.org/10.1007/s12517-012-0758-4
28. El-Nahry AH (2001) An approach for sustainable land use studies of some areas in northwest Nile Delta, Egypt. PhD thesis, Soil Science Department, Faculty of Agriculture, Cairo University
29. Abdel Kawy W (2013) Using GIS modeling to assess the agricultural sustainability in Kafr El-Sheikh Governorate, Nile Delta, Egypt. Arab J Geosci 6:733–747
30. Mohamed ES, Saleh AM, Belal AA (2014) Sustainability indicators for agricultural land use based on GIS spatial modeling in North Sinai – Egypt. Egypt J Remote Sens Space Sci 17:1–15
31. Nawar S (2009) Mapping units of some soils of el-salam canal basin using the geographic information systems (gis). Soil and Water Department, Suez Canal University, Ismailia