

Towards Sustainable Intensification of Sesame-based Cropping Systems Diversification in Northwestern India

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Abstract Despite being largely self-sufficient in food production, Indian agriculture currently faces a slew of problems- productivity is in decline; income gap between farmers and the rest of the workforce is widening and the incessant conversion of agricultural lands into urban landscapes is threatening agricultural intensification. This rapid urbanization coupled with unpredictable climate changes, will put added pressures on land and food. Sesame (*Sesamum indicum* L.) is one of the most versatile and survivor crops that can be grown in semi-arid and arid regions. It has unique attributes that can fit almost any cropping system being a short duration crop with a potential to sustainably intensify crop production through crop diversification. This evidently indicates the potentiality for improvement in yield. We investigated the productivity of sesame sown as sole crop, intercrop and as a sequence crop to enhance its cropping system intensification with the following objectives (i) to identify different sesame-based cropping systems with high productivity and profitability to suit the specific needs of North Gujarat agro ecosystems (ii) the best sustainable land use efficiency as influenced by sesame-based cropping systems intensification. Our result showed that higher system productivity based on sesame equivalent yield (SEY), system profitability in terms of net realization to the growing year and land use efficiency was recorded in sesame + groundnut – castor (8.0 kg/ha/day; Rs. 298.3/ha/day and 79.7%), sesame + greengram – castor systems (7.9 kg/ha/day; Rs. 297.0/ha/day and 74%), sesame – castor (7.3 kg/ha/day; Rs. 274.7/ha/day and 74%) and sesame + hybrid cotton (5.3 kg/ha/day; Rs. 204.5/ha/day and 86%) cropping systems respectively. We concluded that the intensification of sesame-based cropping system could help farmers adapt to the changing climate with greater resilience, net primary productivity and enhanced income through crop(s) diversification. One that emphasizes a climate-smart agriculture strategy for food security, mitigation and adaptation.

Keywords: *cropping system, climate smart agriculture, crop diversification, food security, semi-arid, sesame, sustainable intensification*

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1. Introduction

Indian agriculture currently faces a slew of problems- productivity is in decline and the incessant conversion of agricultural lands into urban landscapes is threatening agricultural intensification. This rapid urbanization coupled with unpredictable climate changes, will put added pressures on land and food [1,2]. Global food system problems as impacted by climate change, population growth, rapid urbanization and pressure on land calls for adaptive approaches to food security [3]. Reference [4] stated that the global population is projected to rise from the current seven billion to nine billion in few decades, thus a 73% (almost three quarters) increase in land productivity will have to meet the future growth in global food demand by 2030, either from yield increases or increases in cropping intensity [5]. The remaining 27%

will come from expansion of the area under cultivation [3,4]. In its save and grow report [1], emphasized that sustainable intensification of crop production through diversification is seen as an innovative strategy capable of feeding the nine billion dreams come 2050 [3]. Several small scale-plot or farm studies across Africa, showcasing practical approaches that deliver intensification *viz*-ecological, socioeconomic and genetic intensification have been reported [2]. Food outputs by sustainable intensification increased yield per hectare by combining the use of new and improved varieties and agronomic-agroecological management (crop yields rose on average by two-fold), and additively by diversification which resulted in the emergence of a range of new crops, that added to the existing staples being cultivated [7].

India imports a substantial portion of its edible oil consumption annually to boost its local production capacity to meet the increasing demand [8]. However, India is a major producer of sesame and its contribution to

the production of sesame seeds in the world is 15.4% in 2012 [9]. Its share in world's exports of hulled sesame is around 60% earning more than USD 1 billion from the export of 200,000 tonnes of sesame seeds [10]. However, sesame productivity is low in India (3.76 t/ha) as compared to world's average (5.59 t/ha) [9].

Sesame is a survivor crop that can be grown in semi-arid and arid regions with unique attributes that can fit almost any cropping system being a short duration crop [11,12], Gujarat state, a semi-arid region in Northwest India is a major producer of sesame which accounts for 12% of the average sesame production in 2008-2011 [13]. The present challenge is how to place crop production systems on a sustainable pedestal operating at high productivity and economic levels in the face of the dreaded impact of climate change on agricultural productivity. The goal of sustainable crop production and management is within agricultural intensification itself [1,14]. This evidently indicates the potentiality for improvement in yield to intensify production through diversification.

Therefore, the aim of this paper is to present a systematic overview of the different sesame based cropping system diversification in Northwest, India; a semi-arid region with significant limitations associated with climate change capable of achieving crop production intensification. We investigated this with the following objectives: (i) to identify different sesame-based cropping system with high productivity and profitability to suit the specific needs of North Gujarat agro ecosystems (ii) the best sustainable land use efficiency as influenced by sesame-based cropping systems diversification.

We follow [7], in his definition of sustainable intensification, as producing more output from the same piece of land while reducing negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services.

Crop diversification is intended to give a wider choice in the production of a variety of crops in a given area so as to intensify production of various crops. Higher profitability and resilience (lessen risk) in production are major considerations. Crop diversification in India is generally viewed as a shift from traditionally grown less remunerative crops to more remunerative crops [15].

2. Materials and Method

2.1. Experimental Site Description

The field experiment was conducted at Sardarkrushinagar Dantiwada Agricultural University Instructional Farm, North agro-climatic zone of Gujarat state, India (Latitude 24° 19' N; Longitude 72° 19' E, Altitude 154.52 meter above mean sea level). The area is characterized by arid and semi-arid tropical climate. The monsoon (rainy) season commenced by the second week of July and retreats by the middle of September with an average rainfall of 840 mm in 32 rainy days and temperature range from 4.9 – 40.4 °C during the growing seasons of July 2011 – April 2012. Generally, crops are grown all year round with an average rainfall of 638 mm in 25 rainy days. The regular winter season starts by the middle of October and it continues till the end of February. December and January are the coldest months of the

winter season and the summer season commences with at the beginning of March and ends by the middle of June; April and May are the hottest months of the year. The cropping history of the experimental plot during the preceding three years was a Guar-Mustard-Fallow sequence all year round.

2.2. Soil Sampling Description

Soil samples were randomly collected within the experimental area from 0-30 cm depth prior to experimentation and analyzed for nitrogen (N), phosphorus (P), potassium (K) and soil organic carbon (SOC) content by standard procedures for optimal fertilizer recommendation. The soil texture was loamy sand; low in organic carbon (0.18%) and available N (195 kg/ha), medium in available P (12.7 kg/ha) and high in K (215 kg/ha).

2.3. Experimental Design

The experiment was laid out in a randomized complete block design with 10 different sesame-based cropping systems treatments replicated four times. Solecropping–intercropping–sequential cropping systems were followed, comprising sesame as sole; intercropped with greengram, groundnut and cotton sown in the monsoon season. Castor, mustard and wheat were sown in winter season as sequence crops after the harvest of the monsoon crops. A total of seven crops were grown in 40 experimental plots with gross plot area of (6.3 by 5.4 m).

2.3.1. Treatment Details

- T₁: Sesame – Wheat
- T₂: Sesame – Castor
- T₃: Sesame – Mustard
- T₄: Sesame + Greengram – Wheat
- T₅: Sesame + Greengram – Castor
- T₆: Sesame + Greengram – Mustard
- T₇: Sesame + Groundnut – Wheat
- T₈: Sesame + Groundnut – Castor
- T₉: Sesame + Groundnut – Mustard
- T₁₀: Sesame + Hybrid Cotton.

2.3.2. Sowing Method and Date

Sesame, greengram, groundnut and mustard were sown by drilling method at 45 by 15 cm inter-intra row spacing, wheat was drilled at 22.5 by 10 cm inter-intra row spacing cm, cotton and castor were sown by dibbling at 90 by 60 cm and 90 by 90 cm respectively. Certified seeds of sesame at the rate of 3 kg/ha, 18 kg/ha for greengram, 120 kg/ha for groundnut, 3 kg/ha for cotton, 5 kg/ha for castor, 4 kg/ha for mustard and 3 kg/ha for cotton crop were sown at depth of 3-5 cm for sesame, mustard, wheat, green gram and cotton and 7 cm for groundnut and castor. The harvest durations of the different crops ranges from 75 – 234 days.

Table 1. Sowing and Maturing Dates of Crops

Crops	Sowing date	Days to maturity
Sesame	18 July 2011	80
Greengram	18 July 2011	75
Groundnut	18 July 2011	101
Cotton	18 July 2011	188 – 234
Castor	10 Oct. 2011	162 – 190
Mustard	20 Oct. 2011	119
Wheat	25 Nov. 2011	110

2.3.3. Fertilizer, Irrigation and Weed Management

The recommended dose of nitrogen and phosphorus were applied to each crop. The whole quantity of phosphorus was applied as basal dose (time of sowing) for all the crops. Urea was applied as basal dose for greengram and groundnut, while in sesame, mustard and wheat, urea was applied in two equal splits dose (sowing and 30 days respectively) and four equal splits dose for cotton and castor (sowing, 40, 80 and 120 days respectively). Irrigation was applied by furrow (free flow) method at 50% depletion (IW/CPE). A rotary hand weeder was used to control weed twice during the growing stage supplemented with one hand weeding for the long duration crops (cotton and castor).

2.4. Treatment Evaluation and Parameter Estimations

The crop response to treatment application under the present investigation was evaluated on the basis of sesame equivalent yield, system productivity and profitability and land use efficiency.

2.4.1. Sesame Equivalent Yield

Sesame equivalent yield was obtained by adding the yield of sesame and that of the different intercrops and their by-products multiplied by their current respective prices in the local market over the price of sesame.

$$SEY \left(\text{Rs. kg ha}^{-1} \right) = \frac{\left[\begin{array}{l} \text{(Yield of sesame crop} \times \text{Price of sesame crop)} \\ + \text{(Yield of Intercrops} \times \text{Price of intercrops)} \\ + \text{(Yield of winter crops} \times \text{Price of wintercrops)} \end{array} \right]}{\text{Price of sesame}}$$

2.4.2. System Productivity

$$\text{System productivity} = \frac{\text{Sesame equivalent yield}}{365 \text{ days}} \left(\text{kg / ha / day} \right)$$

2.4.3. System Profitability

$$\text{System Profitability} = \frac{\text{Net realization of crop sequence}}{365 \text{ days}} \left(\text{Rs. / ha / day} \right)$$

2.4.4. Land Use Efficiency

$$\text{Land use efficiency (\%)} = \frac{\text{Duration of cropping (days)}}{365 \text{ days}}$$

2.5. Statistical Analysis

Experimental data obtained from the 40 plots were subjected to analysis of variance (ANOVA) in a randomized complete block design performed using Statistical Analysis System, SAS[®] 9.2 Software [16]. Differences between treatment means were compared using Duncan multiple range test (DMRT) at $P < 0.05$.

3. Results and Discussion

3.1. Yield and System Productivity

System productivity across treatments, in terms of sesame equivalent yield (SEY) showed that sesame + groundnut – castor, sesame + greengram – castor and sesame – castor recorded significantly higher productivity compared to the other treatments. The lowest system productivity was recorded in sesame – wheat as depicted in Table 2.

Table 2. Economic Yield, Sesame Equivalent Yield, System Productivity of the different Sesame-based Cropping Systems

Treatments	Rainy (Kharif) (kg/ha)		Winter (Rabi) (kg/ha)	Sesame Equivalent Yield (Rs. kg/ha)	System Productivity (SEY, kg/ha/day)
	Base crop	intercrops			
Sesame – Wheat	582	-	3673	1724	4.7
Sesame – Castor	608	-	3701	2665	7.3
Sesame – Mustard	617	-	2135	1952	5.3
Sesame + Greengram(1:1) – Wheat	347	770	3889	2107	5.8
Sesame + Greengram(1:1) – Castor	343	758	3571	2874	7.9
Sesame + Greengram(1:1) – Mustard	323	741	2038	2132	5.8
Sesame + Groundnut(1:1) – Wheat	310	843	3456	2065	5.7
Sesame + Groundnut(1:1) – Castor	315	889	3333	2883	8.0
Sesame + Groundnut(1:1) – Mustard	318	853	1846	2160	5.9
Sesame + Hybrid Cotton(1:1)	360	contd.	2329	1945	5.3
S.Em. ±	-	-	-	100	-
C.D (P=0.05)	-	-	-	291	-

1USD= *50 IND=Rupees (Rs.). *Based on 2012 exchange rate.

Sesame seed yield was significantly higher in sole than in the intercrops. The results confirm the findings of [17], when sesame was sown as sole compared to intercrop with soybean and blackgram. However, the combined yield of the intercrops was significantly higher for greengram and groundnut respectively compared to sesame sole during rainy season. This corroborate the findings of [18], who reported increase in total productivity when sesame was

intercropped than in sole cropping. Intercrops of sesame with cotton was 6–12% higher than with greengram and groundnut intercrops respectively. These results are in conformity with [19], who observed higher yield when sesame was intercropped with cotton compared to castor. Higher sesame equivalent yield (SEY) was recorded in the system having castor. This was due to the higher seed yield obtained in castor over mustard and the high

prevailing market price it commands over wheat. Sesame + groundnut – castor and sesame + greengram – castor recorded 8% higher productivity as compared to sesame – castor and 41% higher than sesame – wheat. The castor crop in this system was a deciding factor in obtaining higher system productivity resulting from substantial biomass produced.

3.2. System Profitability

System profitability across the different sesame cropping system was the highest in the castor sequence treatments as depicted in Figure 1. Sesame + groundnut – castor obtained the highest profitability (Rs. 298.3/ha/day) closely followed by sesame + greengram – castor (Rs. 297.0/ha/day), sesame – castor (Rs. 274.7/ha/day) and sesame + hybrid cotton (Rs. 204.5/ha/day) respectively, which were significantly higher from the rest of the systems. The lowest system profitability was obtained in sesame – wheat (Rs. 132.6/ha/day). System profitability is a function of the quantity of net primary productivity (biomass) produced, the cost of cultivation and the prevailing market price of the produce to obtain an overall net profit. System profitability across the treatments, in terms of the net realization from the crops to the days in a

year was the highest in castor sequence. Sesame + groundnut – castor secured 0.4% and 9% higher profitability as compared to sesame + greengram – castor and sesame – castor respectively. The castor crop in the system gave an economic advantage in terms of the higher biomass produced. A good indicator of a cropping system to be adopted by a farmer is the actual income received from such system(s). In the above based cropping system evaluated, the treatments were significantly different. In the rainy season, sesame + groundnut secured higher net profit compared to the other treatments. The higher biomass produced in groundnut was the determining factor for securing a higher net profit. For the system net realization (rainy and winter seasons), sesame + groundnut – castor presented the greatest potential by securing the highest profit as compared to the other systems. However, it was significantly at par with sesame + greengram – castor and sesame – castor respectively. The highest net profit in the systems having castor was due to the increased net primary productivity. These results are in conformity with [5], who reported higher systems productivity and profitability in a mustard-maize based cropping system when intercropped than in sole.

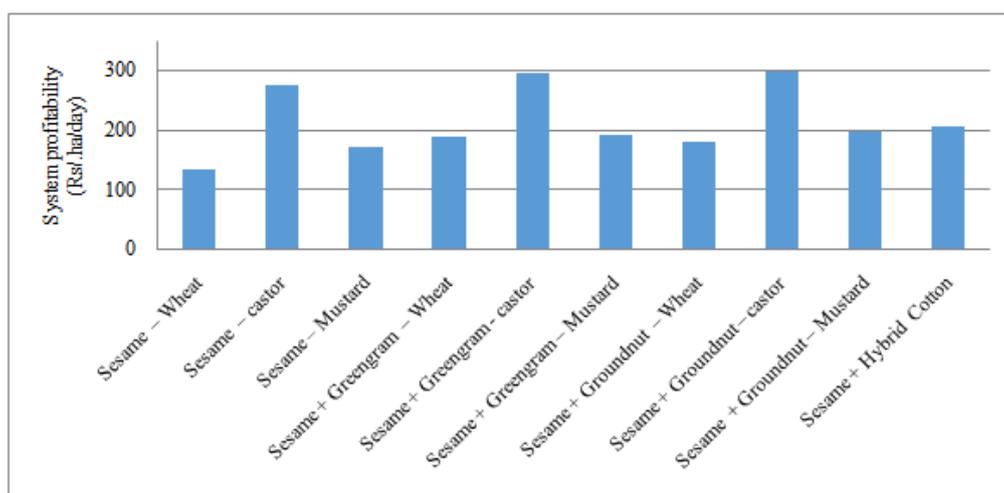


Figure 1. System profitability as influenced by different sesame based cropping systems

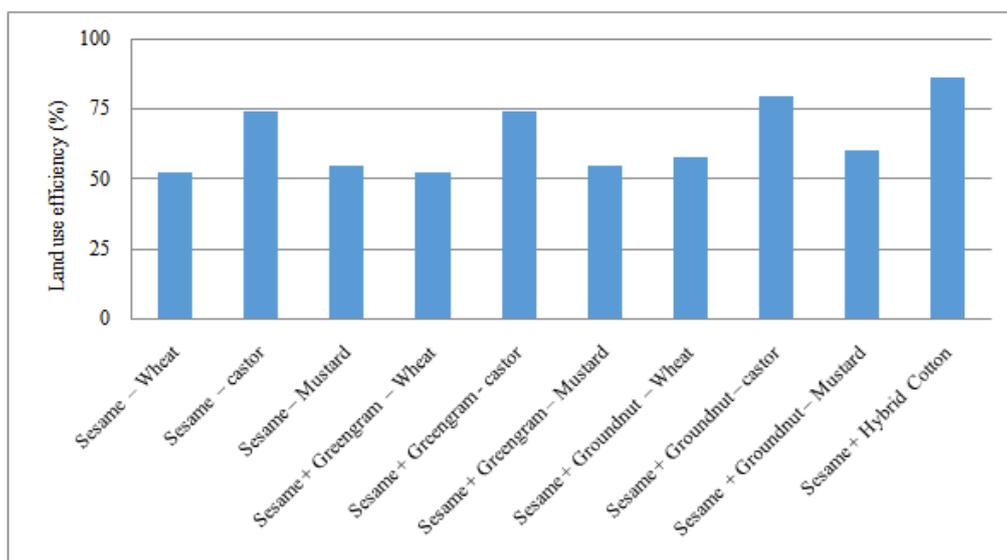


Figure 2. Land use efficiency as influenced by different sesame based cropping systems

3.3. Land Use Efficiency

Sesame + hybrid cotton (86%) recorded the highest system land-use efficiency (LUE) followed by sesame+ groundnut – castor(79.7%), sesame + greengram – castor(74%) and sesame– castor(74%) depicted [Figure 2](#). Lower land use efficiency obtained in sesame – wheat and sesame + greengram – wheat respectively was the resultant duration (shorter) of these cropping systems compared to the other systems. The longer duration of cotton and castor in their respective systems ensured that the cropland was covered for a larger part of the year which in the long run resulted to greater carbon accumulation in the soil. Therefore, elimination of summer fallowing is an important strategy of soil carbon sequestration [20]. This corroborate the findings of [22], who reported higher LUE in a soybean-based cropping systems when summer cropping was included, with resultant cropland occupied for a longer duration. The objective is to maintain a vegetal cover on the soil surface all year round so that biomass carbon can be added/returned to the soil. Consequently, the soil organic carbon pool can be maintained or increased in most semi-arid soils if they are cropped every year with the resultant long-term productivity per unit input of limiting resources (e.g., nutrients, energy) [21].

4. Conclusion

In spite of the abnormal rainfall condition during the growing season, enhanced productivity of sesame-based cropping systems (sesame + groundnut – castor, sesame + greengram – castor, sesame – castor, sesame + hybrid cotton) diversification in the Northern semi-arid region of India has shown the potential of diversification of crops could help farmers adapt to the changing climate with greater productivity and profitability. Cultivation of land all year round by elimination of fallowing is an important strategy of accumulating soil organic matter with the potential of reducing carbon footprint through its sequestration into the soil thus reducing greenhouse gases emissions, enhanced income for farmers from employment generation all through the year. This climate-smart strategy of crop diversification promotes a new paradigm for sustainable and ecological intensification of crop production systems. The intensification of land to produce crop throughout the seasons (year) has become a basis to sustainably increased crop production capable of feeding the increasing population particularly in south Asia and Africa with dwindling and unproductive land area.

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References

- [1] FAO, *Save and Grow-A policymaker's guide to the sustainable intensification of smallholder crop production*, Rome, 2011. [E-book] Available: <http://www.fao.org/ag/save-and-grow/> [Accessed Nov. 25, 2014].
- [2] The Montpellier Panel, *Sustainable Intensification: A New Paradigm for African Agriculture*, 2013. London. [E-book] Available: <http://ag4impact.org/publications/montpellier-panel-report2013/> [Accessed Nov. 25, 2014].
- [3] Godfray, C., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Pretty, J., Robinson, S., Thomas, S. M., & Toulmin, C, "Food security: the challenge of feeding 9 billion people," *Science* 327, 812-818, 2010.
- [4] United Nations Department of Economic and Social Affairs. "Population division, population estimates and projections section". [Online]. Available: http://esa.un.org/wpp/unpp/panel_population.htm. [Accessed May 20, 2013].
- [5] BrijNandan., Sharma, B.C, and ANIL KUMAR, "Mitigating Food Security Options through Climate Resilient Mustard-maize Based Intercropping Sequences for North-western-Himalayas," *Journal of Food Security* 1 (2): 58-64, Dec. 2013.
- [6] FAO. "World agriculture: towards 2015/2030. Rome". [Online]. Available: <http://www.fao.org/docrep/004/y3557e/y3557e00.htm> [Accessed April 24, 2014].
- [7] Pretty J., Toulmin, J., & Williams, S, "Sustainable intensification in African agriculture," *International journal of agricultural sustainability* 9(1). 5-24, 2011
- [8] Dutta, R. "India's soyoil imports seen down in 2014/15 on bumper oilseed crop traders," *Reuters*, [Online]. Available: <http://in.reuters.com/article/2014/09/26/india-soyoil-imports-idINL3N0RR38C20140926> [Accessed Nov. 25, 2014].
- [9] FAOSTAT, "Sesame yield and productivity," [Online]. Available: <http://faostat3.fao.org/compare/E>. 2012. [Accessed Nov. 24, 2014].
- [10] Duhon, S.S., Jyotishi, A., Deshmukh, M.R. and Singh, N.B. "Optimization of sesame production through bio-natural inputs," *in 4th International Crop Science Congress on New directions for a diverse planet*, RA Fischer (ed), Brisbane, Australia, 26 Sept. - 1 Oct. 2004
- [11] Langham, D. R., Riney, J., Smith, G., Wiemers, T., Peeper, D. and Speed, T. "Sesame growers guide". Sesaco Corporation, 2008. [E-book] [Online]. Available: www.sesaco.net
- [12] Bedigian, D. and Harlan, J.R. "Evidence for cultivation of sesame in the ancient world," *Economic Botany*. 40: 137-154, 1986.
- [13] Directorate of Economics & Statistics (DOES), 2012. "Normal estimates-sesamum" Department of Agriculture and Cooperation, Government of India. [Online]. Available: http://eands.dacnet.nic.in/APY_Normal_Estimates-2012-13.htm. [Accessed Nov. 21, 2012].
- [14] Kassam, A. & Friedrich, T. "An ecologically sustainable approach to agricultural production intensification: Global perspectives and developments". *Field Actions Science Reports*, Special Issue 6, April 2012. [Online]. Available: <http://factsreports.revues.org/1382>. [Accessed Nov. 28, 2014].
- [15] Hazra, C.R. Expert consultation on crop diversification in the Asia-Pacific region. FAO Country Report, India. FAO Corporate Documents Repository. [E-book] Available: 2000 <http://www.fao.org/3/a-x6906e.pdf>
- [16] Statistical Analysis System SAS® Statistical Software 9.2 Version.
- [17] Kumar, A. and Thakur, K.S. "Production potential and economic feasibility of sesame-based intercropping with legumes under rainfed conditions,". *Indian Journal of Agricultural Sciences* 76 (3): 183-189, 2006.
- [18] Sarkar R.K., Malik, G.C. and Goswami, S. "Productivity potential and economic feasibility of sesame (*Sesamum indicum*)-based intercropping system with different planting pattern on rainfed upland," *Indian Journal of Agronomy* 48(3):164-167, 2003.
- [19] Bhatt, B.K., Dixit, S. K. and Darj, V. B. "Monetary evaluation of sesame based intercropping systems," *Indian Journal of Agricultural Research* 44 (2): 146-149, 2010.
- [20] Rasmussen, P.E., Goulding, K.W.T., Brown, J.R., Grace, P.R., Janzen, H.H., Korschens, M. "Long-term agroecosystems experiments: assessing agricultural sustainability and global change," *Science* 282: 893-896, 1998.
- [21] Lal, R. "Soil carbon sequestration to mitigate climate change". *Geoderma* 123: 1-22, 2004.
- [22] Prajapat, K., Vyas, A.K., and Dhar S, "Productivity, profitability and land-use efficiency of soybean-based cropping systems under different nutrient-management practices". *Indian Journal of Agronomy* 59 (2): 229-234, 2014.