OPEN ACCESS

1 November, 2018
ISSN 1991-637X
DOI: 10.5897/AJAR
www.academicjournals.org

ACADEMIC JOURNALS
expand your knowledge

About AJAR

The African Journal of Agricultural Research (AJAR) is a double blind peer reviewed journal. AJAR publishes articles in all areas of agriculture such as arid soil research and rehabilitation, agricultural genomics, stored products research, tree fruit production, pesticide science, post-harvest biology and technology, seed science research, irrigation, agricultural engineering, water resources management, agronomy, animal science, physiology and morphology, aquaculture, crop science, dairy science, forestry, freshwater science, horticulture, soil science, weed biology, agricultural economics and agribusiness.

Indexing

Science Citation Index Expanded (ISI), CAB Abstracts, CABI's Global Health Database
Chemical Abstracts (CAS Source Index), Dimensions Database, Google Scholar
Matrix of Information for The Analysis of Journals (MIAR) Microsoft Academic
ResearchGate, The Essential Electronic Agricultural Library (TEEAL)

Open Access Policy

Open Access is a publication model that enables the dissemination of research articles to the global community without restriction through the internet. All articles published under open access can be accessed by anyone with internet connection.

The African Journal of Agricultural Research is an Open Access journal. Abstracts and full texts of all articles published in this journal are freely accessible to everyone immediately after publication without any form of restriction.

Article License

Article Copyright

When an article is published by in the African Journal of Agricultural Research the author(s) of the article retain the copyright of article. Author(s) may republish the article as part of a book or other materials. When reusing a published article, author(s) should;

Cite the original source of the publication when reusing the article. i.e. cite that the article was originally published in the African Journal of Agricultural Research. Include the article DOI
Accept that the article remains published by the African Journal of Agricultural Research (except in occasion of a retraction of the article)
The article is licensed under the Creative Commons Attribution 4.0 International License.

A copyright statement is stated in the abstract page of each article. The following statement is an example of a copyright statement on an abstract page.
Copyright ©2016 Author(s) retains the copyright of this article..

Self-Archiving Policy

The African Journal of Agricultural Research is a RoMEO green journal. This permits authors to archive any version of their article they find most suitable, including the published version on their institutional repository and any other suitable website.
Please see http://www.sherpa.ac.uk/romeo/search.php?issn=1684-5315

Digital Archiving Policy

The African Journal of Agricultural Research is committed to the long-term preservation of its content. All articles published by the journal are preserved by Portico. In addition, the journal encourages authors to archive the published version of their articles on their institutional repositories and as well as other appropriate websites.
https://www.portico.org/publishers/ajournals/

Metadata Harvesting

The African Journal of Agricultural Research encourages metadata harvesting of all its content. The journal fully supports and implements the OAI version 2.0, which comes in a standard XML format. See Harvesting Parameter

Memberships and Standards

Academic Journals strongly supports the Open Access initiative. Abstracts and full texts of all articles published by Academic Journals are freely accessible to everyone immediately after publication.

All articles published by Academic Journals are licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0). This permits anyone to copy, redistribute, remix, transmit and adapt the work provided the original work and source is appropriately cited.

Crossref is an association of scholarly publishers that developed Digital Object Identification (DOI) system for the unique identification published materials. Academic Journals is a member of Crossref and uses the DOI system. All articles published by Academic Journals are issued DOI.

Similarity Check powered by iThenticate is an initiative started by CrossRef to help its members actively engage in efforts to prevent scholarly and professional plagiarism. Academic Journals is a member of Similarity Check.

CrossRef Cited-by Linking (formerly Forward Linking) is a service that allows you to discover how your publications are being cited and to incorporate that information into your online publication platform. Academic Journals is a member of CrossRef Cited-by.

Academic Journals is a member of the International Digital Publishing Forum (IDPF). The IDPF is the global trade and standards organization dedicated to the development and promotion of electronic publishing and content consumption.

Contact

Editorial Office: ajar@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: http://www.academicjournals.org/journal/AJAR

Submit manuscript online http://ms.academicjournals.org

Academic Journals

73023 Victoria Island, Lagos, Nigeria

ICEA Building, 17th Floor, Kenyatta Avenue, Nairobi, Kenya

Editors

Editorial Board Members

Table of Content

Vol. 13(44), pp. 2471-2476, 1 November, 2018
DOI: 10.5897/AJAR2018.13429
Article Number: 4B33B6759097
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Groundwater quality monitoring for agriculture irrigated in Catolé Do Rocha, Paraíba State, Brazil

Evandro Franklin Mesquita[1*], Lourival Ferreira Cavalcante[2], Francisco Thiago Coelho Bezerra[2], Jackson Mesquita Alves[1], José Thyago Aires Souza[2], Caio Silva Sousa[1], Antonio Gustavo Luna Souto[2] and Danila Araújo de Lima [2]

[1]Universidade Estadual da Paraíba, Center for Agrarian and Human Sciences (CCHA), Zip Code: 58.884 – 000, Catolé do Rocha, Paraíba, Brazil.
[2]Universidade Federal da Paraíba, Center for Agricultural Sciences, Zip Code: 58.397-000, Areia, Paraíba. Brazil.

Received 1 August, 2018; Accepted 19 September, 2018

The electrical conductivity and of cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and anions (Cl^{-}, CO_3^{2-}, HCO_3^{-} and SO_4^{2}) contents of the water an Amazon well, from State University of Paraíba, Catolé do Rocha city, Paraíba State, Brazil, located in the semi-arid region of the Brazilian High Sertão were evaluated monthly from January to December of year 2017. Despite the increase in electrical conductivity from 0.89 to 1.16 mS cm^{-1} and sodium adsorption ratio (SAR) from 4.43 to 10.45 (mmol $L^{-1})^{1/2}$ did not change the water quality to agriculture. With mean risk to saline (C2) and low risk to exercise sodicity at soil (S1), toxicity and nutritional imbalance to plants, the concentration of dissolved salts increased from 0.57 to 0.74 g L^{-1} between rainy and arid periods. This situation expresses a high increase of almost 30% in the total dissolved salts during the evaluated period and shows the need for systematic monitoring. Simulating the irrigation with a 400 mm blade of this water with 1.16 dS m^{-1}, in 120 days, can add to soil 2,970 kg ha^{-1} of salts, of which 1,892; 633; 258 and 143 kg ha^{-1} are of the sodium, calcium, potassium and magnesium species, respectively.

Key words: Water quality, ionic components of water, salinity of water in well.

INTRODUCTION

Agriculture, in Brazil and worldwide, is the activity that consumes the most water in comparison to the consumption of human, herds and industrial (Oliveira et al., 2013; Holanda et al., 2016). This peculiarity, in part, is due to insufficient and irregular rainfall, high temperature air and soil, low humidity, high evaporation rates and evapotranspiration. Beyond the quantitative aspects (regular rainfall and volume of water available), specifically in agriculture, the world also needs chemical quality water that allows the use in the irrigation without causing high edaphic degradation and high cultures production losses (Cavalcante et al., 2012; Ganiyu et al. 2018). In addition to these inconveniences, the surface and groundwater salt content in semi-arid areas, which is generally above the limits tolerated by plants to human food and animals importance, results in a serious

*Corresponding author. E-mail: elmesquita4@pq.cnpq.br.

irrigated agriculture obstacle (Andrade Júnior et al., 2006; Ammari et al., 2013; Koff et al., 2017). When considering the limitations of water resources, in quantity and quality, and the growing demand for food in the world for nearly fifty years, have awakened as an alternative the use of restrictive water due to the excess of salts for irrigation of plants of economic importance (Costa; 1982; Silva Júnior et al., 1999; Rhoades et al., 2000; Ben-Asher et al., 2006; Holanda et al., 2016; Vieira et al., 2016; Murad et al., 2018). However, even assuming this need not all high waters salt concentration, such as sea water or equivalent concentration, should be used for irrigation. This assertion is based on Ayers and Westcot (1999), Cavalcante et al. (2012) and Holland et al. (2016), when they affirm that plants with food and commercial importance are, in great majority, low or medium tolerance to the water salinity.

The use of water with restrictions due to excess salts in irrigated agriculture, irrespective of the source (surface or underground source), requires the monitoring of the electrical conductivity, cation and dissolved concentrations (Medeiros et al., 2003; Barroso et al., 2011; Jang et al., 2012; Oliveira et al., 2013; Lira et al., 2015; Chu et al., 2016; Rassol et al., 2017; Ganiyu et al., 2018). This monitoring, if possible, should be at various times of the year, considering one or more sources of property, municipality or watershed, making possible a specific panorama and the elaboration of strategies of use of this water resource.

The salinity studies the total concentration of salt mixture effects, or saline complex, dissolved in the irrigation water - CS (g L^{-1}); the value can be estimated by the product between the water electrical conductivity-ECw (dS m^{-1}) and the 0.64 multiplication factor waters with up to 5 dS m^{-1} or 0.80 for salinity water higher than 5 dS m^{-1} (Rhoades et al., 2000). The total salt concentration can also be obtained analytically by the calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+) and sodium (Na^+) quantification in equivalence with chloride (Cl^-), bicarbonate (HCO_3^-), carbonate (CO_3^-) and sulfate (SO_4^{2-}) (Richards, 1954). Toxicity refers to the specific effects of some ions such as sodium, chloride, magnesium, boron and the ratio of sodium to total cations dissolved in water. Sodium is evaluated by the sodium adsorption ratio - SAR (Ayers and Westcot, 1999), by the value of residual sodium carbonate (RSC) which is the difference between the sum of carbonate plus bicarbonate plus calcium plus magnesium RSC = (CO_3^{2-} +HCO_3^-) - (Ca^{2+} + Mg^{2+}) (Richards, 1954; Almeida, 2010; Maskooni et al., 2017). The aim of this study was to monitor monthly the electrical conductivity and the cationic and anionic contents in amazon well water.

MATERIALS AND METHODS

The work was carried out in experimental area of the Center for Human and Agrarian Sciences, State University of Paraíba, Campus - IV, municipally Catolé do Rocha, State of Paraíba, Brazil. Water samples were collected monthly, from January to December 2017, from an Amazon well (6° 21' 11"S, 37° 43' 21" W and 244 m above sea level) with a diameter of 4 m, depth of 11 m and an annual mean daily flow of 2.2 m^3 h^{-1}. The region climate is BSwh', according to Köppen classification (Alvares et al., 2013), defined as hot semi-arid. The municipality rainfall is less than 800 mm and are irregularly distributed in the rainy season, with more than 65% precipitated from February to April month; the annual averages temperature and relative humidity are, respectively, 27°C and below 50%. The soil of the area, according to the criteria of the Brazilian Soil Classification System (Embrapa, 2013) was classified as Eutrophic Entisol. The physical and chemical properties (fertility and salinity) in a sample of 0-0.2 m layer of this soil were analyzed (Embrapa, 2017) with their values given in Table 1.

The electrical conductivity of the water was determined by direct reading in conductivity. Ca^{2+} + Mg^{2+} was analyzed by complexometry with disodium EDTA, using Eriochrome-Black as an indicator. Ca^{2+} determined by complexiometry in the presence of carbonic acid indicator calcone. Na^+ and K^+ were determined flame spectrometer. For CO_3^{2-} and HCO_3^- the titration was with H_2SO_4 using the respective indicators, phenolphthalein and methyl orange. After determination of carbonate and bicarbonate was added K_2CrO_4 and titrated with $AgNO_3$ for determination of Cl^-. SO_4^{2-} was determined in photocolorimeter after the addition of HCl and $BaCl_2.2H_2O$ (Richards, 1954). The average of monthly data of electrical conductivity and ion concentration were related to each other by a regression test. For each ionic component was calculated the minimum, average and maximum (Silva Júnior et al., 1999). The average of the mean electrical conductivity and ion concentration of each component was used to simulate the irrigation full blade 400 mm, according to the following equation (Richards, 1954; Rhoades et al., 2000):

$$Sad = (Ecw \times 0.64 \times Iwd) / 1,000;$$

were: Sad = total salts added by water (kg ha^{-1}); Ecw = Electrical conductivity water (dS m^{-1}); Iwd = Irrigation water depth (mm), 1 mm = 10 m^3 ha^{-1} = 10,000 L ha^{-1}, thus 400 mm is equivalent to 4,000,000 L ha^{-1}. The quantification of each sais added was calculated from the total volume applied and their respective participation in the water.

RESULTS AND DISCUSSION

The electrical conductivity in the period from January to December/2017 increased from 0.89 to 1.16 dS m^{-1} resulting in a saline increase of 30.3%; this value is considered high and already uses moderate restraint (Ayers and Westcot, 1999; Medeiros et al., 2003; Almeida, 2010, Cavalcante et al., 2012, Holanda et al., 2016) the great importance economic cultivated plants. The relation between the electrical conductivity and the total dissolved salts (TDS) in water (Figure 1) was 64%. This level expresses high dispersion, but the increasing factor between both is consistent with Richards (1954) and shows the dependence between the electrical conductivity and the total dissolved salts, with 80% correlation contents salts water dissolved, due to the increase in electrical conductivity of the water. In this way, it is verified that although the electrical conductivity correlates with the content of dissolved salts, it does not faithfully represent the concentration of salts but by its

Table 1. Physical and chemical (fertility and salinity) attributes of the Eutrophic Entisol where the Amazonas well installed.

Physical attributes		Chemical attributes			
		Fertility		Salinity	
Sand (g kg^{-1})	661	pH (in H_2O)	6.7	pH (in extract)	7.7
Silt (g kg^{-1})	213	P (mg kg^{-1})	25	Ecw (dS m^{-1})	1.30
Clay (g kg^{-1})	126	Ca^{2+} ($cmol_c$ kg^{-1})	4.41	Ca^{2+} ($mmol_c$ L^{-1})	3.99
Pd (kg dm^{-3})	1.52	Mg^{2+} ($cmol_c$ kg^{-1})	1.31	Mg^{2+} ($mmol_c$ L^{-1})	1.26
Sd (kg dm^{-3})	2.75	Na^{+} ($cmol_c$ kg^{-1})	0.22	Na^{+} ($mmol_c$ L^{-1})	5.84
Porosity (m^3 m^{-3})	0.45	K^{+} ($cmol_c$ kg^{-1})	0.76	K^{+} ($mmol_c$ L^{-1})	2.17
		H^{+}+Al^{3+} ($cmol_c$ kg^{-1})	0.00	Cl^{-} ($mmol_c$ L^{-1})	10.00
		SB ($cmol_c$ kg^{-1})	6.70	CO_3^{2-} ($mmol_c$ L^{-1})	0.00
		CEC($cmol_c$ kg^{-1})	6.70	HCO_3^{-} ($mmol_c$ L^{-1})	2.98
		ESP (%)	3.28	SO_4^{2-} ($mmol_c$ L^{-1})	0.20
				SAR (mmol $L^{-1})^{1/2}$	3.61

Pd - particle density; Sd - soil density; SB - sum of bases; CEC - cation exchange capacity; ESP - exchangeable sodium percentage; Ecw - water electrical conductivity; SAR - sodium adsorption ratio.

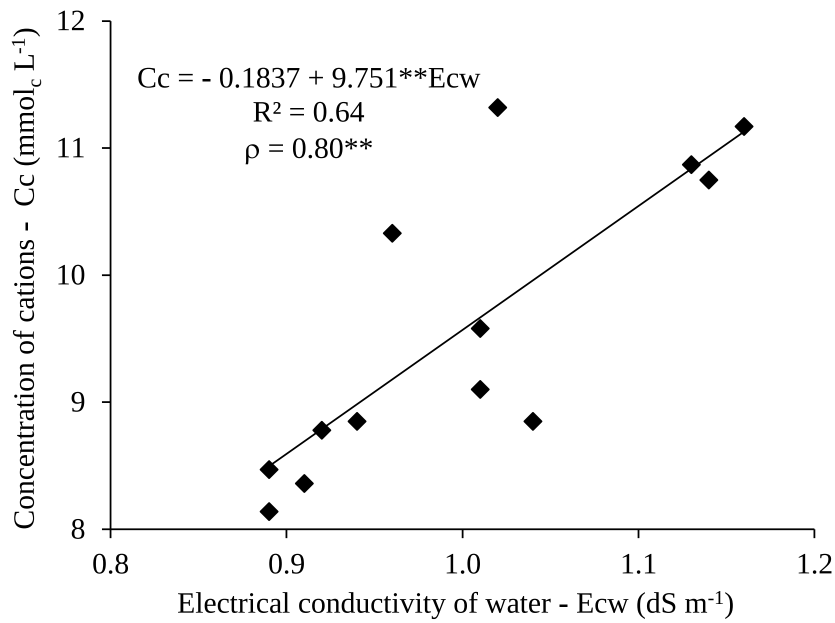

Figure 1. Concentration of cations as a function of the electrical conductivity of water in Amazon well.

value the total solubilized in water (Richards, 1954; Rhoades et al., 2000; Holanda et al., 2016) and in the soil is estimated (Cavalcante et al., 2012; Ribeiro et al., 2016).

In Figure 2, it shows the mean, average and maximum values of cations, anions and electrical conductivity throughout the year 2017. The order of the mean cation contents was 7.06 (Na^{+}) > 1.36 (Ca^{2+}) > 0.83 (Mg^{2+}) > 0.32 (K^{+}) $mmol_c$ L^{-1}, for the anions of 7.45 (Cl^{-}) > 1.87 (HCO_3^{-}) > 0.42 (SO_4^{2-}) > 0.15 (CO_3^{2-}) $mmol_c$ L^{-1} and, the electrical conductivity of water amplitude was 0.89 to 1.16 dS m^{-1} with 1.01 dS m^{-1} mean (Figure 2). These values fluctuate with the mineralogical nature, with the intensity of the transformation of the source material and with the solubility of the primary components of the soils, especially the sodium, calcium and magnesium contents (Ribeiro et al., 2016).

Among the cations the predominance is sodium and anions the chloride, with concentrations in general similar, but with chloride (7.45 $mmol_c$ L^{-1}) supremacy in relation to sodium (7.06 $mmol_c$ L^{-1}) (Figure 3), which is why most scientific investigations refer to both species as

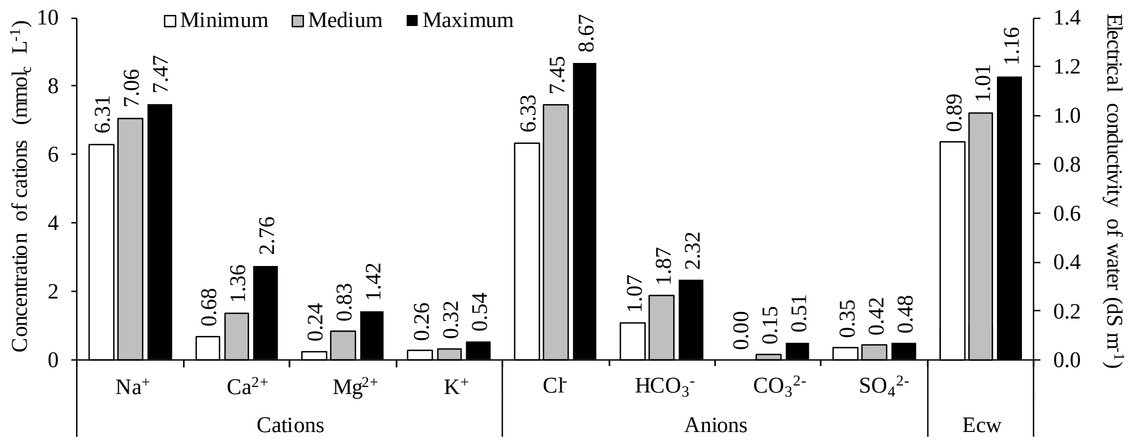

Figure 2. Minimum, mean and maximum values of cations, anions and electrical conductivity of water in Amazon well.

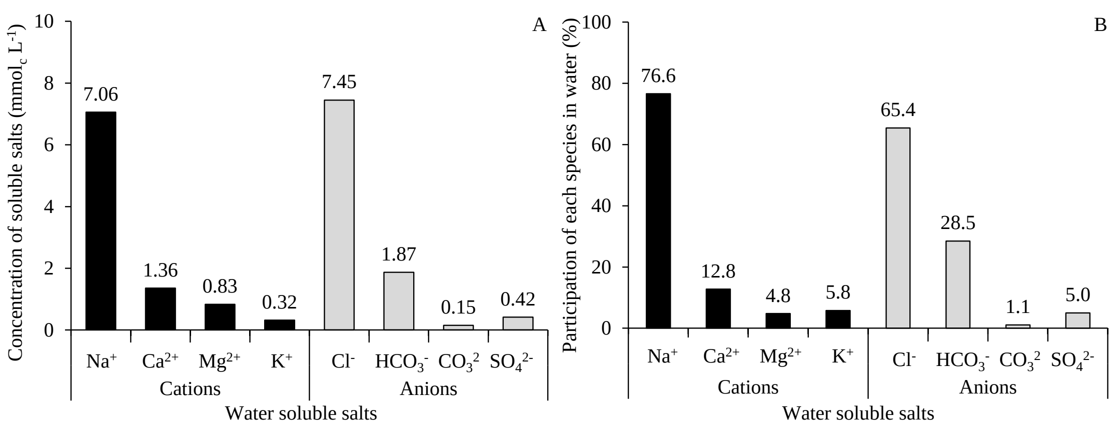

Figure 3. Concentration (A) and percentage participation (B) of soluble ionic species in water of the one Amazon well.

expressed the literature on salinity. This superiority, compared to the other components of each species, is not only due to the aggressive action of Na^+ in the soils physical attributes depletion, but also in the structure loss and pore space reduction to the root growth, nutritional and plant toxicity (Richards, 954; Ayers and Westcot, 1999; Almeida, 2010).

Despite the higher molar concentration of chloride compared to sodium, the percentage share of sodium exceeds chloride within valence, obeying the order 76.6 (Na^+) > 12.8 (Ca^{2+}) > 5.8 (K^+) > 4.8 (Mg^{2+}) for cations and 65.4 (Cl^-) > 28.5 (HCO_3^-) > 5.0 (SO_4^{2-}) > 1.1 (CO_3^{2-}) for ions (Figure 3B). These orders differ from those obtained for the concentrations (Figure 2) because they are calculated based on the concentration in mg L^{-1} and vary according to the equivalent each species weight (Cavalcante et al., 2012). This situation resembles the sequences presented by Silva Júnior et al. (1999), Costa (1982), Medeiros et al. (2003), Andrade Júnior et al. (2006), Leal et al. (2009), Barroso et al. (2011), Oliveira et al. (2013) and Holanda et al. (2016), respectively for crystalline Brazilian Northeast waters in the Paraíba, Piauí, Rio Grande do Norte and Ceará, States all of which are inserted in Brazil semi-arid region.

The reported situation resembles the sequences recorded by Jang et al. (2012) in Taiwan, Hassanli and Ebrahimian (2016) in Karaj, Maskooni et al. (2017) in Iran, Rassol et al. (2016) in Pakistan, Koffi et al. (2017) in Ghana, Gill and Terry (2016) in Australia, Ganiyu et al. (2018) in Nigeria, among many others. The results also show that composition terms and salt content the semi-arid world present situation, even considering the differences in soil source materials, is very similar between the West and the East lands. Waters with electrical conductivity of up to 1.16 dS m^{-1}, even if they had moderate restrictions on plants and soil, if the world had enough water for irrigation to meet the world food and livestock requirements, it would suggest less employment saline waters in agriculture. This statement seems consistent since soil irrigation with depth water 400 mm (1.16 dS m^{-1}) during drought 120 days in the Catolé do Rocha municipality, Paraíba State, Brazil, with Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}, concentrations respectively, 2.59, 1.29, 6.75 and 0.54 $mmol_c$ L^{-1}, would add to the soil a total of 2,970 kg ha^{-1} which salts, 1,892, 633, 258 and 187 kg ha^{-1} are salts of sodium, calcium, potassium and magnesium, respectively.

Conclusions

The Amazon well water electrical conductivity during the 2017 year increased from 0.89 to 1.16 dS m^{-1}. The salts total added to the soil with an irrigation depth of 400 mm was 2,970 kg ha^{-1}, of the 63.7; 21.3; 8.7 and 6.3% corresponded to salts of sodium, calcium, potassium and magnesium. The amplitude of the electrical conductivity and the addition of salts of the soil by a water depth not high, justify the monitoring of the quality of irrigation water in the semiarid region from anywhere in the world.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The authors thank the National Council for Technological Development Scientific (CNPq), the Higher Education Personnel Coordination (CAPES) and the Science Technology in Salinity National Institute (INCTSal), respectively, for the awarding of scientific initiation scholarships in undergraduate, postgraduate Master's degree, PhD and research productivity and financial aid to carry out the project activities.

REFERENCES

Almeida AO (2010). Qualidade da água de irrigação. 1ª ed. Cruz das Almas: Embrapa Mandioca e Fruticultura 227 p.

Alvares CA, Stape JL, Sentelhas PC, Gonçalves JLM, Sparovek, G (2013). Köppen's climate classification map for Brazil. Meteorologische Zeitschrift 22(6):711-728.

Ammari TG, Tahhan R, Abubaker S, Al-Zu'bi Y, Tahboub A, Ta'any R, Abu-Romman S, Al-Manaseer N, Stietiya MH (2013). Soil Salinity Changes in the Jordan Valley Potentially Threaten Sustainable Irrigated Agriculture. Pedosphere 23(3):376-384.

Andrade Júnior AS, Silva EFF, Bastos EA, Melo FB, Leal CM (2006). Uso e qualidade da água subterrânea para irrigação no Semi-Árido piauiense. Revista Brasileira de Engenharia Agrícola e Ambiental 10(4):873-880.

Ayers RS, Westcot DN (1999). A qualidade da água na agricultura. 2ª ed. Campina Grande: UFPB (FAO, Estudos de irrigação e drenagem, 29, revisado) 153 p.

Barroso AF, Gomes EG, Lima AEO, Palácio HAQ, Lima CA (2011). Avaliação da qualidade da água para irrigação na região Centro Sul no Estado do Ceará. Revista Brasileira de Engenharia Agrícola e Ambiental 15(6):588-593.

Ben-Asher J, Tsuyuki I, Sagih M (2006). Irrigation of grapevines with saline water I. Leaf area index, stomatal conductance, transpiration and photosynthesis. Agricultural Water Management 83(1-2):13-21.

Cavalcante LF, Oliveira FA, Gheyi RR, Cavalcante IHL, Santos PD (2012). O maracujazeiro e a salinidade da água. João Pessoa: Sal da Terra, 400 p.

Chu LL, Kang YH, Wan SQ (2016). Effect of different water application intensity and irrigation amount treatments of microirrigation on soil-leaching coastal saline soils of North China. Journal of Integrative Agriculture 15(9):2123-2131.

Costa RG (1982). Caracterização da qualidade de água de irrigação na microrregião homogênea de Catolé do Rocha (MRH -89), Dissertação (Mestrado em Engenharia Agrícola), Universidade Federal da Paraíba. Campina Grande.

Embrapa-Centro Nacional de Pesquisa de Solos (2013). Sistema Brasileiro de Classificação de Solos. 3ª ed. Brasília: Embrapa Solos 353 p.

Ganiyu SA, Badmus BS, Olurin OT, Ojekunle ZO (2018). Evaluation of seasonal variation of water quality using multivariate statistical analysis and irrigation parameter indices in Ajakanga area, Ibadan, Nigeria. Applied Water Science 8(1):8-35.

Gill BC, Terry AD (2016). 'Keeping salt on the farm'- Evaluation of an on-farm salinity management system in the Shepparton irrigation region of South-East Australia. Agricultural Water Management 164(1):291-303.

Hassanli M, Ebrahimian H (2016). Cyclic use of saline and non-saline water to increase water use efficiency and soil sustainability on drip irrigated maize in a semi-arid region. Spanish Journal of Agricultural Research 14(44):1204-1218.

Holanda JS, Amorim JRA, Ferreira Neto M, Holanda AC, Sá FVS (2016). Qualidade da água para irrigação. In: Gheyi HR, Dias NS, Feitosa CF, Gomes Filho E. Manejo da salinidade na agricultura: estudos básicos e aplicados. 2ª ed. Fortaleza: INCTSal. Cap. 4:35-50.

Jang CS, Chen SK, Kuo YM (2012). Establishing an irrigation management plan of sustainable groundwater based on spatial variability of water quality and quantity. Journal of Hydrology 11(1):414-415.

Koffi KV, Obuobie E, Banning A, Wohnlich S (2017). Hydrochemical characteristics of groundwater and surface water for domestic and irrigation purposes in Vea catchment, Northern, Ghana. Environmental Earth Science 76(185):1-19.

Leal CM, Andrade Júnior AS, Sousa WF, Silva EFF, Bastos EA (2009). Qualidade da água subterrânea para fins de irrigação na microrregião de Teresina, Piauí. Irrigation 14(3):276-288.

Lira RM, Santos NA, Silva JS, Barnabé JMC, Barros MS, Soares HR (2015). A utilização de águas de qualidade inferior na agricultura irrigada. Revista GEAMA 1(3):341-362.

Maskooni EK, Kompanizare M, Afzali SF (2017). Chemical assessment of dam water irrigation effects on groundwater qualities in Bigherd plain, Fars Province, Iran. Environmental Earth Science 76(238):1-14.

Medeiros JF, Rodrigo RA, Lisboa RA, Oliveira O, Silva Júnior MJ, Alves LP (2003). Caracterização das águas subterrâneas usadas para irrigação na área produtora de melão da Chapada do Apodi. Revista Brasileira de Engenharia Agrícola e Ambiental 7(3):469-472.

Murad KFI, Hossain A, Fakir OA, Biswas SK, Sarker KK, Rannu RP, Timsina J (2018). Conjunctive use of saline and fresh water increases the productivity of maize in saline coastal region of Bangladesh. Agricultural Water Management 204(2):262-270.

Oliveira HA, Bezerra HN, Araújo JMS, Tavares LAF (2013). Qualidade de águas de poços dos assentamentos da chapada do Apodi - RN para o uso na agricultura. Holos 1(1):64-72.

Rassol A, Xiao T, Farooqi A, Shafeeque M, Liu Y, Kamran MQ, Katsoyiannis IA, Samas E (2017). Quality of tube well water intended for irrigation and human consumption with special emphasis on arsenic contamination at the area of Punjab, Pakistan. Environmental Geochemical Health 39(4):847-863.

Rhoades JD, Kandiah A, Mashali QM (2000). Uso de Águas salinas para produção agricola. Tradução de Gheyi, H. R.; Sousa, J. R.; Queiróz, J. E. Campina Grande: UFPB (Estudos FAO: Irrigação e Drenagem, 48) 117p.
Ribeiro MR, Ribeiro Filho MR, Jacomine PKT (2016). Origem e classificação dos solos afetados por sais. In: Gheyi HR, Dias NS, Feitosa CF, Gomes Filho E. Manejo da salinidade na agricultura: estudos básicos e aplicados. 2ª ed. Fortaleza: INCTSal. Cap. 2:9-16.
Richards LA (1954). Diagnostico y rehabilitación de suelos salinos y sódicos. México: Departamento de Agricultura de los Estados Unidos de América (Manual de Agricultura, 60). 174 p.
Silva Júnior LGA, Gheyi HR, Medeiros JF (1999). Composição química de águas do cristalino do Nordeste brasileiro**.** Revista Brasileira de Engenharia Agrícola e Ambiental 3(1):11-17.
Vieira IGS, Nobre RG, Dias AS, Pinheiro FWA (2016). Cultivation of cherry tomato under irrigation with saline water and nitrogen fertilization. Revista Brasileira de Engenharia Agrícola e Ambiental 20(1):55-61.

Vol. 13(44), pp. 2477-2498, 1 November, 2018
DOI: 10.5897/AJAR2018.13188
Article Number: C2ACC3E59099
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Performance and farmers selection criteria Evaluation of Improved Bread Wheat Varieties

Astawus Esatu Seifu[1*], Firew Mekibib[2] and Tadesse Dessalegn[3].

[1]Department of Technology Multiplication and Seed Research, Ethiopian Agricultural Research Institute, Kulumsa, Ethiopia.
[2]School of Plant Science, Haramaya University, Dire Dewa, Ethiopia.
[3]GIZ/Green Innovation Center, Addis Ababa, Ethiopia.

Received 14 April, 2018; Accepted 30 April, 2018

Bread wheat is one of the most important cereal crops of the world and a staple food for about one third of the world's population and is a major cereal crop in Ethiopia. One of the major challenges in improving food security is to develop varieties that are adapted to specific environment and farmers' needs. Field trials were conducted at two locations, Hitosa (Sero-Anketo kebele) and Limu Bilbilo (Bekoji-Negesso kebele) districts, in Arsi zone of Oromiya regional state, Ethiopia in 2015. The objectives were to identify farmers' and traders' preferences and selection criteria and acceptable varieties among the tasted twenty-five bread wheat varieties through farmers' participation. The experiment was laid out in lattice design with three replications in which farmers participated only in one of the replication for ranking. Farmers and traders identified top seven criteria that are the same at both locations (that is, disease and insect resistance, grain yield, spike size, seed color, tillering capacity, market demand and seed size, except seed weight instead of seed size at Seru-Anketo) for rating of varieties from 1 to 5 scale (1=very poor and 5=excellent). Data analysis was done using SAS and Microsoft Excel. All varieties showed resistant type of infection for the three rusts (Stem, Yellow and Leaf) at Bekoji-Negesso: As all varieties scored <20 ACI. Similarly, at Sero-Anketo, *Kakaba, Digelu* and *Jefferson* ranged under MS to S whereas *Gassay, Hiddasse*, and *Mekelle-02* ranged under MS and MR types of infection for SR, respectively. Grain protein was analyzed and *Hoggana* (14.27%) was found to be the highest. Based on measured trait (rusts resistance) and farmers' and traders preferences ranking; *Bika, Bulluk* and *TAY* for *Bekoji-Negeso* and *Mekelle-4*, *Ogolcho* and *TAY* for Sero-Anketo were recommended with their full production packages. Therefore, participation of farmers in early breeding program could be one of the approaches as to identify the best variety for specific location.

Key words: Direct matrix ranking, grain protein, pairwise ranking matrix, participatory varietal selection (PVS), rust.

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is grown on more land area worldwide than any other crop. In 2013, world production of wheat was 713 million tons, making it third most-produced cereal after maize (1,016 mill t) and rice (745 million tons) (FAOStat, 2015). According to Central Statistical Agency (CSA, 2015) report of Ethiopia, wheat is fourth both in area (1,663,838 ha) and in production (4,231,589 t) after Maize, *tef* and sorghum with an average national yield of 2.54 t ha^{-1}, which is far to global average wheat productivity of 3.33 t ha^{-1} (FAOStat, 2014).

Although useful as a livestock feed, wheat is used mainly as a human food. Wheat provides 21% of the food calories and 20% of the protein for more than 4.5 billion people in 94 developing countries (Von Braun et al., 2010). It has been realized since long that gluten protein largely determines the bread making performance of wheat flour. In Ethiopia, wheat grain is used in the preparation of a range of products such as the traditional stable pancake (“*injera*”), bread (“*dabo*”), local beer (“*tella*”), and several others local food items (that is, “*dabokolo*”, “*genfo”, “kinche*”). Besides, wheat straw is commonly used as roof thatching material, and as a feed for animals. Wheat contributes approximately 200 kcal/day in urban areas, compared to about 310 kcal/day in rural areas. It accounts for about 11% of the national calorie intake (Guush, 2011).

However, development of appropriate crop production technologies for site-specific have been major problem. It is known that there could be many genetic and environmental factors on plant products (Yazici and Bilir, 2017). Agricultural researchers must know farmers’ production constraints. Such a client-driven approach is rather new in many developing countries like Ethiopia (Zewdie, 2004). Participatory research is defined in general as that type of research in which users are involved in the design and not merely in the final testing of a new technology. Participatory plant breeding (PPB), in particular, is that type of plant breeding in which farmers, as well as other partners, such as extension staff, seed producers, traders and NGOs, participate and collaborate in the development of a new variety (Ceccarelli, 2012). Participatory varietal selection (PVS) is the selection by farmers on their own fields of finished or near-finished products from plant breeding programmes. These include released cultivars, varieties in advanced stages of testing, and well-characterized material such as advanced non-segregating lines in inbreeding crops, or advanced populations in out-breeding crops. Witcombe et al. (1996) discussed the contrasting impacts of PVS and PPB on biodiversity.

Rigid release requirements and unrepresentative testing conditions lead to mismatches between what breeders offer and what farmers desire (Witcombe and Virk, 1997). A high incidence of genotype by environment (GxE) interactions also complicates the testing picture in cropping systems cultivated in marginal environments (Ceccarelli et al., 1996).

Breeding and cultivar introduction programs produce and evaluate many varieties. These varieties may produce high yield in trials on the research station, but sometimes do not perform well in farmers’ fields, or may lack a quality trait that is important to farmers. Participatory variety selection is a simple way for breeders and agronomists to learn which varieties perform well on-farm and preferred by farmers (Ceccarelli, 2012).

Participatory varietal selection to identify preferred cultivars has three phases: Identifying farmers’ needs; searching for suitable material to test with farmers; and experimentation on farmers’ fields. PVS can be effectively used to identify farmers acceptable varieties that are better than old and obsolete varieties with which farmers stick for long period (Joshi and Witcombe, 1996). A very important advantage of PVS is that the adoption of new cultivars is much faster than under the formal crop improvement and also the spread of varieties from farmer-to-farmer through the local seed system can be very fast, thus guaranteeing a further good adoption (Bellon and Reeves, 2002). The targeted beneficiaries from participatory crop improvement may be resource poor farmers in marginal areas where solely local varieties or landraces cultivated, or farmers in potential areas who were dependent on old improved varieties (Boef and Ogliari, 2008). There is an opportunity to extract much greater value from agro-ecology based breeding, as opposed to the “broadly-adapted” (but not really well adapted) varieties currently available (Dawit, 2010).

Ceccarelli (2012) identified three common characteristics of most agricultural research programmes that might help explain its limited impact in marginal areas: (i) The research agenda is usually decided unilaterally by the scientists and is not discussed with the user, (ii) Agricultural research is typically organized in compartments, that is, disciplines and/or commodities (for example breeding and agronomy, or breeding programmes of specific crops), and seldom uses an integrated approach; this contrasts with the integration existing at farm level and, (iii) There is a disproportional development between the large number of technologies generated by the agricultural scientists and the relatively small number of them actually adopted and used by the farmers. In Ethiopia, for example, over 122 varieties of cereals, legumes and vegetables have been released, but only 12 varieties had been adopted by farmers (Mekbib, 1997), and similar examples are known in many countries.

Researchers may not be aware of some of the important characters that are preferred by farmers. Instead they focuses on agronomic performance (trial like yield, lodging, duration, and disease resistance), but farmers consider many other features of new variety when deciding whether to adopt or not. For example in Ethiopia, farmers identified high yield, resistance to sprouting and lodging, seed color and size, and baking

*Corresponding author. E-mail: astawusesatu@gmail.com.

quality as important agronomic characters and their perceptions about some of these characteristics positively influenced their adoption of modern wheat varieties (Bekele et al., 2000). Farmers may concern straw quantity and palatability, harvestability, threshability and storability. These factors are very hard to evaluate in conventional variety testing programs, but may be strongly related to farmer's decision on adoption. However, in PVS trials farmers express their opinion and preference about varieties under evaluation (IRRI, 2006).

Improved bean varieties in East Africa are probably the best-known example of the successful application of PVS, which has catalyzed bean crop improvement in several countries including Rwanda, Tanzania, and Malawi (Weltzien et al., 2003). In their use of the PPB and PVS approaches, the Debre Zeit and Melkassa research centers of the EIAR showed the increased participation of farmers in tef and haricot bean seed production, respectively, along with the increased adoption of the accepted varieties (Assefa et al., 2005; Belay et al., 2006). Similarly, various researchers from Ethiopia have made investigations on PVS in different crops such as common bean (Mekbib, 1997; Asrat and Fitsum, 2008; Mekonen, 2011; Fekadu, 2013), barley (Zerihun et al., 2012), maize (Mulatu and Zeleke, 2002; Daniel et al., 2014), faba bean (Tafere et al., 2012), bread wheat (Kassa et al., 2003; Alebachew, 2012; Molla and Tsedalu, 2012; Assefa et al., 2014), sorghum (Mulatu and Belete, 2001), and tef (Belay et al., 2006). Therefore, the main goal of experimenting with farmers, through PVS, is important to address their information needs about new and released technologies and solutions to problems in a way that is relevant, cheap, systematic, and has low risk for them. So, through PVS, a broader choice of varieties was offered (a basket of choices) that matched their needs in adaptation and quality traits.

MATERIALS AND METHODS

Description of the experimental sites

The field trials were conducted at two locations in the southwest part of Ethiopia in Arsi zone of Oromiya regional state during 2015 main cropping season at Sero-Anketo kebele (=peasant association) of Hitosa district (=woreda) and at Bekoji-Negesso kebele of Limu-bilbilo district as indicated in Figure 1.

Sero-Anketo is located about 22 km north of KARC and 140 km southeast of Addis Ababa and Bekoji-Negesso is located about 65 km south of KARC and 140 km southeast of Addis Ababa, within bread wheat belt districts in the region. Bekoji-Negesso is located at latitude of 7°32′ 37″ N and longitude of 39°15′ 21″ E and the site have Clay (Nitosols) type of soil. The area is located at higher altitude of 2780 m a.s.l. having 1020 mm annual rainfall and 7.9 and 18.6°C minimum and maximum average annual temperature, representing highland and high rainfall types of agro-ecology. Sero-Anketo is located at mid-altitude of 2250 m.a.s.l. and geographically lay at 8°07′ 31″ N and 39° 16′ 31″ E with loam soil type. The cropping systems in these districts have dominated by diversified field crop production and some horticultural crops. Major field crop grown in these areas were; wheat, barley, faba bean, field pea, oil seed, potato, etc. in rain fed condition.

Experimental materials

Twenty-five improved bread wheat varieties (released and new) were evaluated for their performance in the two sites (Table 1). The varieties have been recently released at federal and regional level from different research institutes or centers but not all tested on those study areas of the districts.

Treatments and experimental design

The trials were conducted using an incomplete block design (partially balanced lattice design) with three replications, each consisting of five incomplete. Randomization was done following the basic plan for 5×5 partially balanced lattice design of triple lattice and twenty-five varieties randomly assigned to each five incomplete blocks in each replications. Every plot has a size of 1.2 m × 2.5 m (3 m^2). The spacing between replications, blocks and plots were 1, 1 and 0.4 m, respectively with 0.2 m row spacing. Planting was done in rows at seed rate of 150 kg ha^{-1}.

Field management and practices

All the recommended agronomic practices have applied throughout the growing season. The land was ploughed three times starting from June, 2015 till planting and after leveling, rows were made by using row marker; planting was carried out in 25 June and 7 July, 2015 at Bekoji station and Sero-Anketo, respectively. Nitrogen and phosphorus fertilizers were applied as per recommendation in the form of Urea (46% N) and diammonium phosphate (18% N and 46% P_2O_5) each at the rate of 100 kg/ha. Harvesting and threshing was done manually.

Data collected

Composite soil samples at 15 cm depth were collected from each trial site just before planting, for soil analysis. Grain yield was determined after its MC was determined and adjusted to 12.5%.

The soil physical and chemical properties of the experimental areas

Composite soil sample of the study sites collected just before planting and analyzed for soil physical and chemical properties (Table 2). The optimal pH range for most plants is between 5.5 and 7.0. The result of soil analysis showed that soil pH of 6.7 and 5.2 were determined at Sero-Anketo and Bekoji-Negesso sites, respectively. The result approaches with the optimum soil pH range of 5.5 to 6.5 for wheat production (http://www.cropnutrition.com/efu-soil-ph#soil-acidity accessed 11/4/2016).

Weather condition during the experimental period

The amount of rainfall for main season (June, July, August and September) of 2015 was low as compared to thirteen years mean rainfall of each month in both locations. A total seasonal RF of 396 and 534 mm was received in four growing months (June, July, August and September) of 2015 at Bekoji and Iteya stations, respectively (Figures 2 and 3). Wheat is cultivated in the region

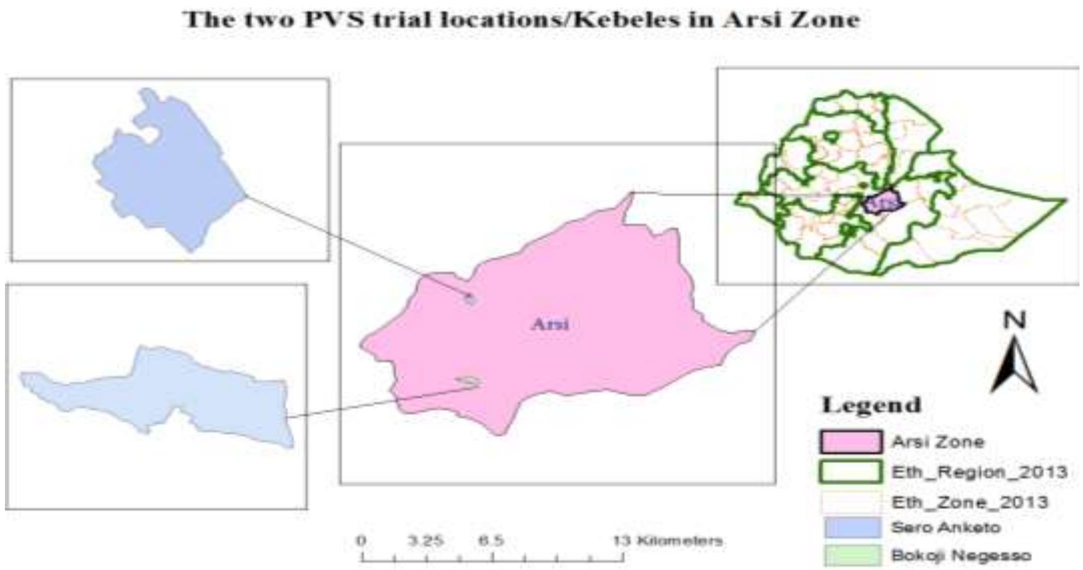

Figure 1. Map of study areas.

Table 1. Description of bread wheat varieties evaluated.

S/N	Varieties/genotype	Institution	Year of release	Adaptation zone	
				Altitude	Rainfall
1	*Honqolo*/ETBW 5879	KARC/EIAR	2014	2200-2600	750-1500
2	*Bika*/ETBW 6095	KARC/EIAR	2014	2200-2600	750-1500
3	*Mandoyu*/Worrakatta/Pastor	SARC/OARC	2014	2200-2500	750-1500
4	*Bulluk/*UTQE96/3/PYN/BAU//MILLAN	BARC/ EIAR	2015	-	-
5	*Hiddasse*/ETBW5795	KARC/EIAR	2012	2100-2800	>600
6	*Ogolcho*/ETBW5520	KARC/EIAR	2012	1500-2100	500-800
7	*Hoggana*/ETBW5780	KARC/EIAR		2200-2800	800-1200
8	*Hulluka*/ ETBW5496	KARC/EIAR	2012	2200-2800	>600
9	*Mekelle-03*/M17SAWSN-79	TARI/TARI	2012	1980-2500	300-500
10	*Mekelle-4*/FRTI-1	TARI/TARI	2013	1980-2500	300-500
11	*Shorima*/ ETBW 5483	KARC/EIAR	2011	2100-2700	700-1100
12	*Mekelle-01*/HUW-468	KARC/EIAR	2011	1980-2500	300-500
13	*Mekelle-02*/HI-1418	MeARC/TARI	2011	1980-2500	300-500
14	*Ga'ambo/ QUIAU#2*	WARC/EIAR	2011	650-2400	Irrigation
15	*Kakaba*/Picaflor#1	KARC/EIAR	2010	1500-2200	500-800
16	*Danda'a*/Danphe#1	KARC/EIAR	2010	2000-2600	>600
17	*Gassay*/ HAR-3730	AdARC/AARI	2007	1500-2200	500-800
18	*Alidoro*/ HK-14-R251	HoARC/EIAR	2007	2200-2900	≥500
19	*Digelu*/SHA 7/KAUZ or HAR3116	KARC/EIAR	2005	2000-2600	>600
20	TAY/ ET-12 D4/HAR 604 (1)	AdARC/AARI	2005	750-2500	>500
21	*Sofumar*/ HAR-1889	SARC/OARI	2000	2000-2600	>600
22	*Mada-Wolabu*/ HAR-1480	SARC/OARI	2000	2200-2900	≥500
23	Pavon-76	KARC/EIAR	1982	750-2500	>500
24	Jefferson	OARI/MORREL	2012	1500-2200	500-800
25	Kingbird	KARC/EIAR	2014	1500-2200	500-800

KARC, Kulumsa Agricultural Research Center; AlamARC, Alamata Agricultural Research Center; AdARC , Adet Agricultural Research Center; SARC, Sinana Agricultural Research Center; MeARC, Mekelle Agricultural Research Center; HoARC, Holleta Agricultural Research Center; OARI, Oromiya Agricultural Research Institute; WARC, Werer Agricultural Research Center; BARC, Bako Agricultural Research Center; AARI, Amara Agricultural Research Institute; TARI, Tigray Agricultural Research Institute; EIAR, Ethiopian Institute of Agricultural Research.

Table 2. Soil physical and chemical properties of the experimental areas, in Arsi zone.

Location	Soil pH(1:2) soil distilled water ratio	Available P (ppm)	Nitrogen (%)	OC (%)	OM (%)
Sero-Anketo	6.7	273.31[¥]	0.25	3.39	5.84 or (OCx1.724)
Bekoji-Negesso	5.2	7.05	0.23	2.73	4.71

Source: Agricultural chemistry laboratory, KARC, EIAR (2016); *OM=organic matter, OC=Organic Carbon, ppm=parts per million; = [¥] value is more than expected.

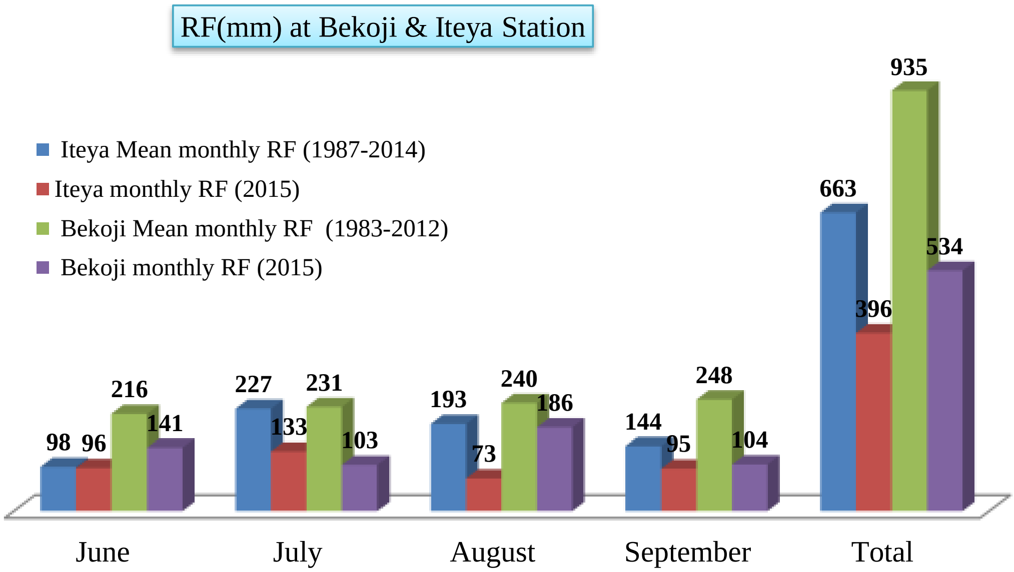

Figure 2. Mean monthly rainfall (RF) for more than twenty-eight years and monthly RF of the growing season (2015) (Bekoji station) and (Iteya stations) districts.
Source*:* KARC Meteorology Research Division.

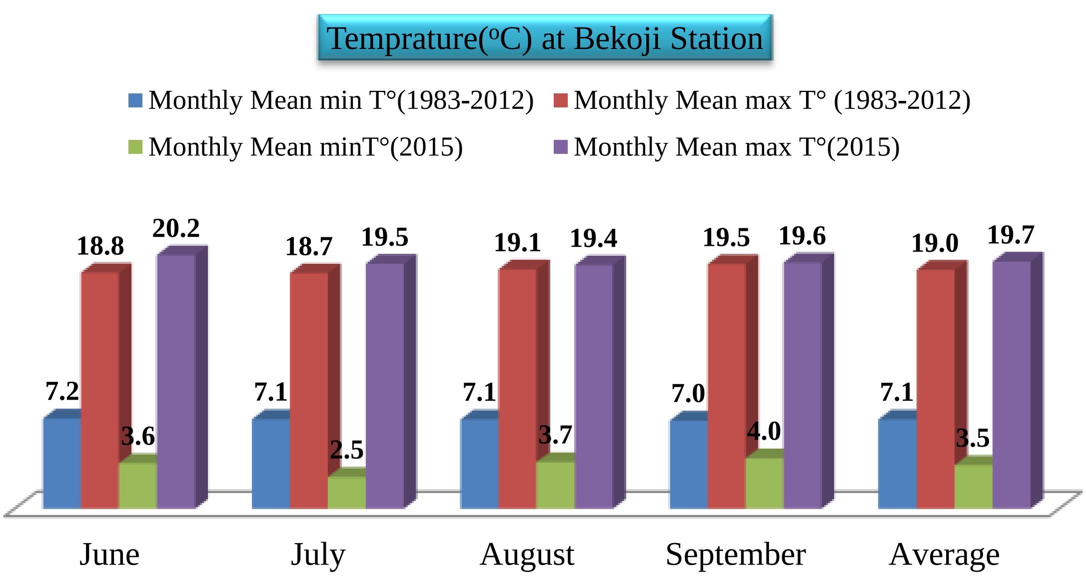

Figure 3. Monthly mean minimum and maximum temperature for thirteen years and growing season (2015) at Limu-Bilbilo (Bekoji station).
Source*:* KARC Meteorology Research Division.

Table 3. Field responses or infection types and assigned constant values.

Field response	Symbol	Constant value
Immune	I	0
Resistant	R	0.2
Moderately resistant	MR	0.4
Intermediate or M	M	0.6
Moderately susceptible	MS	0.8
Susceptible	S	1

where annual precipitation occurs from 250 to 1750 mm, though 75% wheat area falls where annual rainfall precipitation occurs between 375 to 875 mm. Region with 625.4 to 870 mm rainfall are most suitable for wheat cultivation (Jaiswal, 2009).

Rust diseases reaction

The reaction of experimental bread wheat varieties against rusts was scored using visual assessment at random samples of each varieties of wheat by observing the spore severity on the leaves for both leaf and yellow rust and additionally on stem in case of stem rust. Field response was recorded two times; when the crop growth stage was on average between the medium milk and early maturity stages according to Zodaks et al. (1974). Rusts intensities was recorded according to modified Cobb scale as proposed by Peterson et al. (1948) based upon severity as percentage of the plant infected as scale: Trace (<5), 5, 10, 20, 40, 60 and 100% infection and plant response (type of disease reaction) or infection type using the method of Roelf et al. (1992) as shown in Table 3. Severity and response readings were combined; the three rusts (stem, leaf and yellow) were recorded in the classical manner, giving the severity on the modified Cobb scale, along with the field response. After the last disease score when the disease progress ceased, the field severity data were converted to coefficient of infection (CI) by multiplying constant values of field response according to Stubbs et al. (1986) to rank or rate the varieties. Then the average CI (ACI) was determined by adding the CI of replications and divided by the number of replications. Varieties with coefficient of infections ranging from 0 to 20 was considered as resistant (R) while 20 to 30, 30 to 40, 40 to 60 and 60 to 100 were moderately resistance (MR), moderately susceptible (MS), moderately susceptible to susceptible (MSS) and susceptible (S), respectively.

Participatory varietal selection

In PVS work, the participating farmers were bread wheat growers with strong interest in participating and some representatives of the main ethnic and social groups in the community. Consequently, the researchers together with the district agricultural worker identified and selected farmers and fields for the trials. More than forty farmers of both sexes participated and each site has about twenty evaluators of both female and male.

Before starting evaluation of the varieties, a clear-cut explanation, including objectives, was given to the farmers. One randomly assigned replication was selected for evaluation at each site. Farmers observed and evaluated the varieties in three developmental stages: At vegetative, flowering and maturation stages. The overall performances of the varieties, for field preferences, were evaluated at maturation stage. Before the final selection was made, farmers were invited to evaluate the test varieties at vegetative and flowering stages by allowing farmers to identify reasons/criteria of selections and rate each variety, while observing.

The bread wheat varieties were evaluated using farmers' selection criteria. Farmers were exposed to identify a set of characteristics that they find important in their wheat varieties. Even though they identified many selection criteria, they agreed to use seven characteristics (selection criteria) in common (that is, disease and insect resistance, grain yield, spike size, seed color, tillering capacity, market demand and seed size/weight) for final selection on both sites. This is in agreement with Bekele et al. (2000), Kassa et al. (2003) and Alebachew (2012) where farmers identified high yield, tillering capacity, disease resistance, seed color and size, and baking quality as important agronomic characters and their perceptions about some of these characteristics positively influenced their adoption of modern wheat varieties. Similarly, Asaye et al. (2014) reported farmers employed seven different parameters to select their preferred varieties including plant stand, number of tillers, seed coat color, seed size, spike length, number of kernels and disease resistance.

Both direct matrix ranking and pair wise ranking methods were used to rank the tested varieties. In matrix ranking, farmers were advised to rate the performance of each variety with respect to each selection criteria as: (1 = very poor, 2 = poor, 3 = good, 4 = very good and 5 = excellent). In addition, they also gave rating of importance (a relative weight) for each selection criteria as: (3 = very important, 2 = important and 1 = less important) based on consensus where differences were solved by discussion (Boef and Thijssen, 2006). Scoring was done by major vote/hand by group of farmers participated in the selection. Scores of each variety were multiplied by the relative weight of a given character to get the result and then added with the results of other characters/criteria to find out the total score of a given variety and their ranks (Tables 7 and 8). A matrix was prepared as per the selection criteria; wheat varieties were listed in the column and criteria in the row. The performance of the wheat varieties were evaluated and compared among each other and among the study sites.

The pair wise ranking method consists ranking of varieties based on pair wise comparisons of the variety according to attributes: e.g., seed size, seed color, disease free seed, plumpness and uniform sized seed, based on the seed, as these contributes to high market demand/premium price and for other needs. Pair wise ranking has been a useful tool whenever it is important to explore and discuss the criteria for decision making between and among attributes/ alternatives.

Determination of grain protein content

A major quality attribute of wheat is its protein content. The importance for protein content stems from its reputation for being an indicator of gluten content and dough quality. When wheat grain or flour is analyzed for protein content, the material is completely digested to ammonia (in the Kjeldahl method) or to nitrogen (by Dumas analysis). As a result, there is complete destruction of

Table 4. Each location mean values of grain protein of the tested bread wheat varieties.

Variety	Mean value			
	S/Anketo		B/Negeso	
	Protein (%)	GYLD (kg/ha)	Protein (%)	GYLD (kg/ha)
Honqolo	14.07bcd	5027.3bc	11.10bcd	6348.30defgh
Bika	15.03abcd	4996.7bcd	12.23abc	7109.0abcd
Mandoyu	15.13abcd	4451.7cde	12.33abc	6395.3defgh
Bulluk	15.27abc	4525.3cde	12.40ab	7783a
Hiddasse	14.9abcd	4590.3bcde	11.80abcd	5859.7ghij
Ogolcho	13.50d	5227.7ab	12.17abc	5270.3jk
Hoggana	16.37a	3259.3f	12.17abc	7070.7abcd
Hulluka	14.53bcd	4638.0bcde	11.90abcd	6665.0cdef
Mekelle-3	14.57bcd	4689.3bcde	11.10bcd	6656.0cdef
Mekelle-4	13.80bcd	5894.0a	11.90abcd	4999.7k
Shorima	14.80abcd	4981.0bcd	11.87abcd	7718.3a
Mekelle-1	13.83bcd	4982.3bcd	12.03abcd	5760.0ghijk
Mekelle-2	13.80bcd	4602.7bcde	12.10abc	6506.7cdefg
Ga'ambo	14.07bcd	5096.7abc	11.23bcd	7260.7abc
Kakaba	14.20bcd	4530.7bcde	11.13bcd	6449.7defgh
Danda'a	13.60cd	5358.7ab	11.10bcd	5717.7hijk
Gassay	13.77cd	4746.3bcde	11.00cd	6344.0defgh
Alidoro	15.47ab	4178.3de	11.40abcd	6894.3bcde
Digelu	14.07bcd	3919.3ef	10.70d	5760.3ghij
TAY	14.73abcd	5203.0abc	12.23abc	7632.7ab
Sofumar	14.63bcd	4016.0ef	11.27bcd	6473.3defgh
Mada-Wolabu	14.37bcd	4591.7bcde	12.33abc	6015.7fghij
Pavon-76	14.47bcd	5149.7abc	11.83abcd	6196.7efghi
Jefferson	14.93abcd	4636.7bcde	12.77a	5513.3ijk
Kingbird	14.97abcd	4508.3cde	11.97abcd	6260.0efghi
Mean	14.52	4712.04	11.76	6426.41
LSD(0.05)	1.68	832.05	1.40	784.58
CV (%)	3.63	5.55	3.73	3.83

Means in the same column followed by the same letters are not significantly different at 5% level of significance according to tukey's studentized range (HSD) test for Protein % = Grain protein (%) and GYLD = grain yield(kg/ha) at S/Anketo-Sero-Anketo and B/Negeso-Bekoji-Negesso.

information about protein structure and function (Wrigley and Bekes, 2001). Therefore, in this study the routine practice today for determination of protein content that not actually involve digestion but rather a correlative procedure near-infrared spectroscopy was used.

The grains of each variety at each location were tested for their total grain protein percentage by using near-infrared spectroscopy (Infratec™ 1241 Grain Analyzer). Three hundred grams (300 g) of grain was used for the analysis of protein from each plot. The machine was adjusted to analyze the average grain protein percentage of ten sub samples per sample (300 g) or per plot in each replication for each location.

Data analysis

The data were subjected to ANOVA for significance test. Error variance of the individual location was tested for homogeneity; and the combined analysis of variance over the two locations was performed as per the formula given by Gomez and Gomez (1984). Data analysis was done using the SAS computer program, version 9.0 (SAS, 2002). The ANOVA was performed to determine the significances of differences between varieties and between variety-location combinations. Mean separations were conducted using Tukey's Studentized Range (HSD) test at 0.05 probability level. Microsoft Excel was used for the descriptive analysis preference ranking.

RESULTS AND DISCUSSION

Total grain protein content and grain yield of bread wheat

The individual location analysis of variance showed highly significant ($P \leq 0.01$) differences at each location for grain protein content and grain yield (Appendix Tables 1). The analysis of variance over locations revealed highly significant ($P \leq 0.01$) difference among varieties, locations and their interactions for grain protein content and grain yield (Appendix Table 2). The individual location mean values are presented in Table 4.

Table 5. Pair wise ranking of farmers' selection criteria for bread wheat varieties at Bekoji-Negesso.

No.	Criteria	Disease and insect resistance	Grain yield	Spike size	Seed color	Tillering capacity	Market demand	Seed size	Total score	Rank
1	Disease and insect resistance	X							6	1
2	Grain yield	Disease and insect resistance	X						5	2
3	Spike size	Disease and insect resistance	Grain yield	X					1	5
4	Seed color	Disease and insect resistance	Grain yield	Seed color	X				1	5
5	Tillering capacity	Disease and insect resistance	Grain yield	Tillering capacity	Tillering capacity	X			4	3
6	Market demand	Disease and insect resistance	Grain yield	Market demand	Market demand	Tillering capacity	X		3	4
7	Seed size	Disease and insect resistance	Grain yield	Spike size	Seed size	Tillering capacity	Market demand	X	1	5

The major emphasis in wheat has been high protein content for nutritional enhancement and improved processing performance. The total protein contents varied from 13.5% (*Ogolcho*) to 16.4% (*Hoggana*) and from 10.7% (*Digelu*) to 12.8% (Jefferson) at Sero-Anketo and Bekoji-Negesso, respectively. Because grains were collected from plants grown under different conditions in field trait at each location during the same growing season, the influence of environmental factors and/or varietal variation could be the factors for such variation of the total grain protein. Vogel et al. (1978) reported that protein content of 12,600 wheat lines from the USDA World Wheat Collection ranged from about 7 to 22% protein content with the genetic component accounting for about a third of the variation (that is, about 5%). The greater part of the variation was due to non-genetic factors and this strong environmental impact has made breeding for high protein difficult (Shewry, 2007). In addition, it should be noted that rainfall from anthesis to maturity, and soil physical and chemical characteristics (Figure 2 and Table 2) could be the cause for significant difference between the two locations (Appendix Table 2). The mean total proteins within each location did not vary much among tested bread wheat varieties (2.87% at Sero-Anketo and 2.07% at Bekoji-Negesso), but relatively higher variation was found between locations (5.67%).

Generally, higher protein contents were recorded at Sero-Anketo than Bekoji-Negesso. This may be probably due to environmental factors including rainfall, growing temperature, and soil fertility, while genetic differences existed in wheat varieties. Relatively excessive rainfall at Bekoji-Negesso than Sero-Anketo may result to available nitrogen to be leached. The final protein concentration depends on the nitrogen availability during the crop cycle (Stone and Savin, 1999). In addition, as wheat is a cool season plant, relatively higher temperature at Sero-Anketo that occurred after heading and during grain fill affected wheat plant to store fewer carbohydrates (yield) and conversely stored more protein. Water stress can also accelerate leaf senescence, which can impact assimilate supply for seed fill. Longevity of the green tissue in the parent plant during grain development may be a factor in yield. In wheat the leaves become yellow (that is, senesce) before the ear does, and the latter may be the more important in providing photosynthetate at the late stages of maturity. At this time, however, respiration by the grain may exceed the net import of sugars and other substrates, resulting in a small loss in grain weight (Bewley et al., 2013).

Farmers' participatory evaluation and selection criteria for the tested varieties

Participatory variety selection clearly showed which criteria (Table 5 and 6) and which varieties (Tables 7 and 8) the farmers preferred. Farmers' needed a good number of characters in their wheat varieties during discussions. They cited many selection criteria at different stages in both locations: broad leaf, green leaf, good tiller and uniform stand, rust (yellow rust) and insect resistance (shoofly) were among the best criteria chosen at early tillering stage. At flowering stage, criteria like tillering capacity, rusts and insect resistance (aphids), uniform flowering, thick stock, and medium height were preferred. At physiological maturity to harvesting stage: medium and uniform maturity, cool wind resistance (even if it is not a frequent problem), spike size, seeds per spike, spike density, seed color, seed weight, disease resistance, grain yield, tillering capacity, shattering and viviparous resistance were mentioned as selection criteria. However, farmers' in both locations suggested seven same criteria as final selection criteria and ranked using pair-wise ranking as shown in Table 5 and 6. Similarly, Mulatu and Zeleke (2002) and Mekonen (2011) stated that, in a refinement exercise using pairwise comparison the excessive criteria list was

Table 6. Pair wise ranking of farmers' selection criteria for bread wheat varieties in Sero-Anketo.

No.	Criteria	Disease and pest resistance	Grain yield	Spike size	Seed color	Tillering capacity	Market demand	Seed weight	Total score	Rank
1	Disease and pest resistance	X							3	4
2	Grain yield	Grain yield	X						6	1
3	Spike size	Disease and pest resistance	Grain yield	X					2	5
4	Seed color	Disease and pest resistance	Grain yield	Spike size	X				0	7
5	Tillering capacity	Tillering capacity	Grain yield	Tillering capacity	Tillering capacity	X			4	3
6	Market demand	Disease and pest resistance	Grain yield	Spike size	Market demand	Tillering capacity	X		1	6
7	Seed weight	Disease and pest resistance	Grain yield	Seed weight	Seed weight	Seed weight	Seed weight	X	5	2

reduced to the trait, which the majority of the respective village farmers want a crop to have. Such targeted selection efforts have a much higher rate of success and of progress from selection than programs that have to consider multiple traits, for multiple systems as selection criteria.

Top seven criteria were prioritized according to total scores and ranked through pair wise system at Sero-Anketo (Table 6). High yield had the highest score and ranked 1st followed by seed weight and market demand; seed color were the least ranked according to pair wise ranking of top seven criteria, as market availability for farmers in this area has not been such a problem although white colored seed fetch high price. Generally, this indicated that the main target of farmers in this area was getting high yielding variety with good quality grain (Table 6). At Bekoji-Negesso, disease and insect resistance was ranked first and grain yield were ranked second as such altitude have been favorable for rusts development. Earliness was not such important criteria at both locations since seasonal rainfall shortage was not a problem but farmers have preferred medium maturing varieties. However, in some cropping seasons like 2015, e.g. shortage of rainfall at Sero-Anketo is alarming that breeders should develop early to medium maturing varieties in the future. However, high yield with better quality grain were the main criteria at both locations.

Farmers' evaluation of tested bread wheat varieties

The evaluators ranked the varieties in each location based on total score of the suggested selection criteria. Ranking of the varieties for each selection criteria was done based on evaluators common score agreement/ consensus and women's vote were equally considered as men's during scoring. Farmers' evaluations of bread wheat varieties using direct matrix ranking on the field are shown in Tables 7 and 8 and pair wise ranking scores on seed are given in Appendix Tables 3 and 4.

Direct matrix scoring of varieties based on selected criteria in the field at Bekoji-Negesso showed that varieties *Danda'a*, *Shorima*, TAY, *Mada-Wolabu, Hiddasse*, *Sofumar*, *Gassay*, *Bulluk* and *Bika* were ranked first to nine, respectively. In contrast, *Hulluka*, Jeffersson, *Mekelle-4* and the most dominating variety *Kakaba* were the least scored (Table 7). Disease and insect resistance was the most important criteria among others for field ranking of varieties; as rust diseases have been the most important criteria since the higher altitudes are suitable for the development of rusts, causing high yield lose. Besides, grain yield, tillering capacity and spike size were also important. Similarly, Kassa et al. (2003) and Alebachew (2012) identified grain yield and spike size as farmers' important criteria.

The first nine varieties ranked based on farmers scoring at Sero Anketo, from first to nine, were *Mekelle-4*, *Danda'a*, *Hiddasse*, *Ogolcho*, *Honqolo*, *Bika, Shorima*, *Mekelle-01* and TAY(Table 8). The newly adapted variety for this location was *Mekelle-4, which* ranked first at Sero-Anketo. Variety *Danda'a* was preferred at both locations although it showed up to 40S severity reaction for stem rust at Sero-Anketo. Grain yield and tillering capacity were the most important selection criteria in this area; which is in agreement with Alebachew (2012) for bread wheat. Besides, market demand and seed size were also among the very important criteria in which plump seed with white seed color have high demand in market with premium price.

Marketability evaluation of bread wheat varieties

Majority of the farmers have sold their wheat

Table 7. Direct matrix ranking evaluation of bread wheat varieties by group of farmers' (on field) at Bekoji-Negoso (n=22)[Ω].

Variety \ Relative Weight	Ranking of selection criteria for each variety							Total scores	Rank
	Disease and insect resistance	Grain yield	Spike size	Seed color	Tillering capacity	Market demand	Seed size		
	3	3	2	2	3	2	3		
Honqolo	4(12)	4(12)	3(6)	4(8)	5(15)	4(8)	3(9)	70	14
Bika	4(12)	4(12)	5(10)	5(10)	2(6)	5(10)	5(15)	75	9
Mandoyu	4(12)	3(9)	3(6)	4(8)	4(12)	4(8)	4(12)	67	17
Bulluk	5(15)	2(6)	3(6)	5(10)	5(15)	5(10)	5(15)	77	7
Hiddasse	2(6)	4(12)	5(10)	5(10)	5(15)	5(10)	5(15)	78	5
Ogolcho	4(12)	4(12)	5(10)	3(6)	3(9)	4(8)	4(12)	69	16
Hoggana	4(12)	4(12)	3(6)	1(2)	5(15)	1(2)	3(9)	58	19
Hulluka	3(9)	2(6)	2(4)	2(4)	2(6)	2(4)	3(9)	42	25
Mekelle-3	4(12)	4(12)	3(6)	1(2)	5(15)	2(4)	4(12)	63	18
Mekelle-4	1(3)	1(3)	4(8)	4(8)	2(6)	4(8)	4(12)	48	23
Shorima	5(15)	5(15)	3(6)	5(10)	5(15)	5(10)	5(15)	86	2
Mekelle-1	1(3)	1(3)	3(6)	4(8)	5(15)	5(10)	4(12)	57	20
Mekelle-2	3(9)	3(9)	4(8)	4(8)	5(15)	5(10)	4(12)	71	12
Ga'ambo	4(12)	5(15)	4(8)	4(8)	2(6)	5(10)	5(15)	74	10
Kakaba	2(6)	3(9)	3(6)	5(10)	2(6)	4(8)	5(15)	52	22
Danda'a	4(12)	5(15)	5(10)	5(10)	5(15)	5(10)	5(15)	87	1
Gassay	3(9)	5(15)	5(10)	4(8)	5(15)	4(8)	4(12)	77	7
Alidoro	5(15)	5(15)	5(10)	1(2)	5(15)	1(2)	4(12)	71	12
Digelu	1(3)	4(12)	4(8)	5(10)	5(15)	5(10)	4(12)	70	14
TAY	5(15)	4(12)	5(10)	4(8)	5(15)	5(10)	5(15)	85	3
Sofumar	5(15)	4(12)	4(8)	4(8)	5(15)	4(8)	4(12)	78	5
Mada-Wolabu	5(15)	4(12)	5(10)	4(8)	5(15)	5(10)	5(15)	85	3
Pavon-76	2(6)	2(6)	2(4)	3(6)	5(15)	4(8)	4(12)	57	20
Jefferson	3(9)	1(3)	2(4)	1(2)	4(12)	1(2)	4(12)	44	24
Kingbird	3(9)	3(9)	4(8)	5(10)	4(12)	5(10)	5(15)	73	11

-[Ω]number of participants =22 (male = 16, female = 6). -Rating of performance of a variety for a selection criteria: 5 = excellent, 4 = very good, 3 = good, 2 = poor and 1= very poor. Relative weight of a selection criteria: 3 = Very important, 2 = important and 1 = less important. -The numbers in the parenthesis indicates the product of relative weight of the selection criterion and the performance of a variety given by farmers, traders and consumers.

produce to traders and then traders have sold it either to factories or to consumers; farmers could also directly sold to the factories. At locations (Iteya and Bekoji), both female and male traders and consumers were participated in setting criteria for direct and pair wise ranking of varieties. The seed of each variety was packed in transparent polythene bags for grain ranking. The result of direct matrix ranking (Table 9 and Figure 4d) at Iteya (Sero-Anketo) showed that varieties *Bika*, *Hiddasse*, *Mekelle-4*, *Kakaba* and kingbird were ranked first and Meda-welabu ranked sixth for

Table 8. Direct matrix ranking evaluation of bread wheat varieties by group of farmers' (on field) at Sero-Anketo (n=24) [Ω].

Variety \ Relative weight	Ranking of selection criteria for each variety								
	Disease and insect resistance	Grain yield	Spike size	Seed color	Tillering capacity	Market demand	Seed size	Total score	Rank
	2	3	2	2	3	3	3		
Honqolo	5(10)	5(15)	5(10)	4(8)	5(15)	3(9)	3(9)	76	3
Bika	5(10)	4(12)	2(4)	5(10)	3(9)	5(15)	5(15)	75	6
Mandoyu	5(10)	3(9)	2(4)	4(8)	4(12)	4(12)	4(12)	67	13
Bulluk	4(8)	3(9)	3(6)	3(6)	3(9)	3(9)	4(12)	59	20
Hiddasse	3(6)	5(15)	3(6)	5(10)	3(9)	5(15)	5(15)	76	3
Ogolcho	5(10)	4(12)	5(10)	4(8)	4(12)	4(12)	4(12)	76	3
Hoggana	5(10)	1(3)	4(8)	2(4)	5(15)	2(6)	2(6)	52	22
Hulluka	4(8)	5(15)	3(6)	3(6)	1(3)	3(9)	3(9)	56	21
Mekelle-3	5(10)	5(15)	5(10)	2(4)	4(12)	2(6)	4(12)	69	11
Mekelle-4	5(10)	5(15)	5(10)	5(10)	5(15)	5(15)	5(15)	90	1
Shorima	5(10)	5(15)	4(8)	3(6)	4(12)	4(12)	4(12)	75	6
Mekelle-1	4(8)	5(15)	4(8)	4(8)	4(12)	4(12)	4(12)	75	6
Mekelle-2	4(8)	4(12)	4(8)	4(8)	2(6)	4(12)	3(9)	63	18
Ga'ambo	5(10)	3(9)	3(6)	4(8)	2(6)	4(12)	4(12)	63	18
Kakaba	2(4)	3(9)	3(6)	5(10)	2(6)	5(15)	5(15)	65	14
Danda'a	5(10)	5(15)	5(10)	4(8)	5(15)	3(9)	4(12)	79	2
Gassay	2(4)	3(9)	4(8)	4(8)	4(12)	4(12)	4(12)	65	14
Alidoro	4(8)	1(3)	5(10)	2(4)	4(12)	2(6)	2(6)	49	24
Digelu	1(2)	1(3)	1(2)	3(6)	1(3)	3(9)	3(9)	34	25
TAY	5(10)	5(15)	5(10)	4(8)	2(6)	4(12)	4(12)	73	9
Sofumar	4(8)	2(6)	4(8)	4(8)	4(12)	4(12)	4(12)	66	13
Mada-Wolabu	4(8)	4(12)	4(8)	4(8)	3(9)	4(12)	5(15)	72	10
Pavon-76	4(8)	3(9)	3(6)	4(8)	3(9)	4(12)	4(12)	64	17
Jefferson	2(4)	4(12)	3(6)	2(4)	2(6)	2(6)	4(12)	50	23
Kingbird	4(8)	1(3)	4(8)	5(10)	2(6)	5(15)	5(15)	65	14

- [Ω]number of participants=24 (male = 17, female = 7). -, Rating of performance of a variety for a selection criteria: 5 = excellent, 4 = very good, 3 = good, 2 = poor and 1= very poor. Relative weight of a selection criteria: 3 = Very important, 2 = important and 1 = less important. -The numbers in the parenthesis indicates the product of relative weight of the selection criterion and the performance of a variety given by farmers, traders and consumers.

their market value. Seed color, plumpness and large seed were the main criteria for their selection. Varieties *Bika*, *Bulluk*, *Hiddasse*, *Kakaba, Danda'a, Shorima* and Kingbird were selected first at Bekoji (Bekoji-Negesso) (Table 9 and Figure 4d)). The selected varieties had white seed color, plump, uniform sized and large seeded as compared to others and these criteria were expected to have good flour and brea

Table 9. Direct matrix ranking on marketability of bread wheat varieties by traders and consumers, at Bekoji and Iteya, Arsi.

Variety \ Relative weight	Sero=Anketo (n=7) [Ω]				Bekoji-Negesso (n=6) [Ω]			
	Seed color	Plump/uniform size	Seed size	Rank	Seed color	Plump/uniform size	Seed size	Rank
	3	2	3		3	2	3	
Honqolo	4(12)	3(6)	3(9)	18	4(12)	4(8)	3(9)	18
Bika	5(15)	5(10)	5(15)	1	5(15)	5(10)	5(15)	1
Mandoyu	4(12)	4(8)	4(12)	7	4(12)	4(8)	4(12)	14
Bulluk	3(9)	3(6)	4(12)	18	5(15)	5(10)	5(15)	1
Hiddasse	5(15)	5(10)	5(15)	1	5(15)	5(10)	5(15)	1
Ogolcho	4(12)	4(8)	4(12)	7	3(9)	4(8)	4(12)	18
Hoggana	2(6)	2(4)	2(6)	24	1(3)	1(2)	3(9)	25
Hulluka	3(9)	3(6)	3(9)	20	2(6)	2(4)	3(9)	21
Mekelle-3	2(6)	2(4)	4(12)	22	1(3)	2(4)	4(12)	21
Mekelle-4	5(15)	5(10)	5(15)	1	4(12)	4(8)	4(12)	14
Shorima	3(9)	4(8)	4(12)	16	5(15)	5(10)	5(15)	1
Mekelle-1	4(12)	4(8)	4(12)	7	4(12)	5(10)	4(12)	12
Mekelle-2	4(12)	4(8)	3(9)	16	4(12)	5(10)	4(12)	12
Ga'ambo	4(12)	4(8)	4(12)	7	4(12)	5(10)	5(15)	8
Kakaba	5(15)	5(10)	5(15)	1	5(15)	5(10)	5(15)	1
Danda'a	4(12)	3(6)	4(12)	15	5(15)	5(10)	5(15)	1
Gassay	4(12)	4(8)	4(12)	7	4(12)	4(8)	4(12)	14
Alidoro	2(6)	2(4)	2(6)	24	1(3)	1(2)	4(12)	23
Digelu	3(9)	3(6)	3(9)	20	5(15)	5(10)	4(12)	8
TAY	4(12)	4(8)	4(12)	7	4(12)	5(10)	5(15)	8
Sofumar	4(12)	4(8)	4(12)	7	4(12)	4(8)	4(12)	14
Mada-Wolabu	4(12)	4(8)	5(15)	6	4(12)	5(10)	5(15)	8
Pavon-76	4(12)	4(8)	4(12)	7	3(9)	4(8)	4(12)	18
Jefferson	2(6)	2(4)	4(12)	22	1(3)	1(2)	4(12)	23
Kingbird	5(15)	5(10)	5(15)	1	5(15)	5(10)	5(15)	1

- [Ω]number of participants = Iteya=7 (2 F & 5 M) and Bekoji=6 (2 F & 5 M). Rating of performance of a variety for a selection criteria: 5 = excellent, 4 = very good, 3 = good, 2 = poor and 1= very poor; Relative weight of a selection criteria: 3 = Very important, 2 = important and 1 = less important. The numbers in the parenthesis indicates the product of relative weight of the selection criterion and the performance of a variety given by farmers, traders and consumers.

quality for wheat flour factories and consumers.

Besides these criteria, we had asked some traders about the consumers' needs of wheat grain at grain store (Figure 5). According to traders, consumers preferred to buy wheat grain that comes from mid highland (having comparatively higher temperature than highlands) than highlands (cool) areas. "The reason is the bread made from wheat grain grown at highland areas, having high rainfall and cool temperature; do not absorb much water, the dough and bread could melt (less loaf volume) and the bread dried quickly" said the trader. These may be affected by protein content. The scientific research studied in protein revealed that both quantity and quality of protein affect bread-making property like water absorption, oxidation requirements, loaf volume and crumb characteristics (Finney, 1984). Water absorption in the flour is increased with increasing protein content, resulting large loaf volume and soften bread. It also shows effect on staling rates (bread with higher protein content can be stored longer) (Maliki et al., 1980). Usually, grain protein percent increases when environmental conditions like drought and high temperature hinder grain yield to reach its potential (Fowler, 2003). Both genotype and the environment in which wheat is grown affect grain protein content and composition. Protein percentage in grains grown at the higher temperature is higher than those grown at the lower temperature, and protein content in wheat grain normally decreases with the increase in grain yield (Simmonds 1995).

Bika, *Hiddasse* and *Kakaba* were among the three best varieties preferred based on marketability evaluation by traders and consumers (Table 9). *Hoggana*, *Alidoro*, Jefferson and *Mekelle-03* were selected least at both locations as their seed had red, shriveled, non-uniform or small seeded or their combinations.

Figure 4. Farmers' preference ranking at different growth stages and the seed of varieties. (a) Farmers are trying to select varieties based on their preferences at vegetative stage. (b) Farmers are trying to identify selection criteria and rank their preferences at flowering/dough stage. (c) Similarly, farmers are identifying selection criteria and preference ranking of wheat varieties at physiological maturity. (d) Direct and pairwise ranking of seed of wheat varieties by traders and consumers based on their preference/marketability.

In Pair wise ranking of varieties, *Mekelle-02* and *Kakaba* ranked first and, *Hiddasse* and *Meda-welabu* both ranked third followed by *Ga'mbo* and TAY by traders and consumers around Iteya based on their grain traits (Appendix Tables 4). In contrast, Jefferson, *Alidoro, Mekele-03, Digelu* and *Hulluka* ranked least. Similarly, the traders and consumers at Bekoji identified *Bika*, *Hiddasse* and *Danda'a* as the best and Kingbird, *Shorima* and *Kakaba* ranked fourth to sixth, respectively (Appendix Table 3). Seed color, plumpness, seed size, seed uniformity or their combination were traits used for ranking in both locations. Similarly, Alebachew (2012) indicated that the most important criteria for marketability in bread wheat were grain color, plumpness and seed size. In addition, Belay *et al.* (2006) identified seed color, driven by market forces, is the overriding selection criterion in tef.

Overall ranking of performance, farmers' preferences and marketability of bread wheat varieties

Performance ranking is based on the mean grain yield of the variety obtained from individual location whereas

Figure 5. Researchers asking traders about the consumers' needs of wheat grain at grain store.

preferences and marketability ranks are the average ranks of varieties based on selection criteria using direct matrix and pair wise ranking by farmers and other actors both on field and on seed. The overall ranking, which is used to identify the final best variety/ies for the location, is based on the average rank of performance, preference and marketability (Tables 4, 7, 8 and 9 and Appendix Tables 3 and 4). All ranks were done using "rank and percentile" under "Data analysis" in Excel, to rank each variable/criteria and overall rank in descending order, except disease and insect pest resistance which is in ascending order. Best variety was selected for a location depending on performance, overall rank and disease reaction.

Varieties *Shorima* and *Mekelle-4* were the best at Bekoji-Negesso and Sero-Anketo, respectively, based on farmers' preferences, yield and rust resistance (Table 10). However, *Mekelle-4* was moderately susceptible (20MS) (Appendix Table 5) for both leaf rust (LR) and stem rust (SR) with average coefficient of infection (ACI) of 5.33 for LR and 8.13 for SR (Table 11).

Bika, Shorima, Bulluk and TAY at Bekoji-Negesso and *Mekelle-4, Ogolcho, Bika* and TAY at Sero-Anketo were among the most preferred varieties in which each has better yield and good in both field and marketability preferences ranking. These top preferred varieties at both locations showed resistant type reaction to rusts infection and have been selected for these locations (Tables 10 and 11). The overall ranking for the above selected top varieties showed that the high yielder varieties also top ranked by farmers, traders and/or consumers based on both field and marketability preferences ranking. This also showed the positive input or relationship of farmers' preferences with researchers. However, some high yielding varieties may not preferred by evaluators, e.g. *Hoggena, Hulluka and Mekelle-3* at Bekoji-Negesso and *Danda'a* at Sero-Anketo have relatively high yield but ranked less based on farmers on field and traders and consumers marketability preferences. In other case, *Hiddase* and *Danda'a* at Bekoji-Negesso and *Kakaba* and *Meda-Wolabu* at Sero-Anketo was relatively low yielder but have good overall preference ranking due to their preferred seed for market and consumption (Table 10). This indicated that the field performances and the quality of the grain (in terms of color, plumpness and size) were affected by biotic and abiotic factors like rainfall shortage, diseases and the crop phenological characteristics.

Newly introduced variety to these areas, *Mekelle-4*, and the other variety *Ogolcho* performed better and preferred by evaluators at Sero-Anketo but these varieties were yield and preferred least at Bekoji-Negesso (Table 10). This may be due to specific adaptation of varieties for both yield and seed quality and was also reflected by farmers perspective in which they tend to identify high yielder and quality seed (color and size) for their localities. Zewdie (2004) indicated that development of appropriate crop production technologies require a

Table 10. Mean performance (kg/ha) and farmer overall preference ranking of wheat varieties at two locations.

Variety	Ranks at Bekoji-Negesso					Ranks at Sero-Anketo				
	Perf≈	Preference	Marketability		Overall ranking	Perf≈	Preference	Marketability		Overall ranking
		Direct matrix	Direct matrix	Pair wise			Direct matrix	Direct matrix	Pair wise	
Honqolo	14	14	18	20	17	7	3	18	19	15
Bika	5	9	1	1	2	8	6	1	7	2
Mandoyu	13	17	14	14	15	21	13	7	16	18
Bulluk	1	7	1	7	2	19	20	18	18	21
Hiddasse	19	5	1	1	6	17	3	1	3	4
Ogolcho	24	16	18	14	20	3	3	7	9	2
Hoggana	6	19	25	24	22	25	22	24	25	25
Hulluka	8	25	21	19	21	13	21	20	20	20
Mekelle-3	9	18	21	22	19	12	11	22	22	19
Mekelle-4	25	23	14	12	22	1	1	1	7	1
Shorima	2	2	1	5	1	10	6	16	12	12
Mekelle-1	21	20	12	10	16	9	6	7	9	6
Mekelle-2	10	12	12	9	11	15	18	16	1	16
Ga'ambo	4	10	8	10	7	6	18	7	5	10
Kakaba	12	22	1	6	9	18	14	1	1	7
Danda'a	22	1	1	1	5	2	2	15	16	8
Gassay	15	7	14	14	13	11	14	7	14	14
Alidoro	7	12	23	25	18	22	24	24	23	24
Digelu	20	14	8	14	14	24	25	20	20	23
TAY	3	3	8	7	4	4	9	7	6	5
Sofumar	11	5	14	18	12	23	13	7	13	17
Mada-Wolabu	18	3	8	12	9	16	10	6	3	8
Pavon-76	17	20	18	20	24	5	17	7	14	11
Jefferson	23	24	23	23	25	14	23	22	24	22
Kingbird	16	11	1	4	7	20	14	1	9	12

Perf≈ = performance (yield in kg/ha); Preference = farmer preference on the field.

thorough understanding of site-specific problems. Therefore, location specific varietal adaptation is important since it affects the qualitative and quantitative traits of the varieties and varieties should be grown at climatic conditions that suited their growth for good seed or grain production.

Some varieties have preferred good seed that fetch high price but those that have low yield and low field preference ranking may be due to diseases, e.g. *Kakab* and *Hiddasse.* Nevertheless, others were high yielder but farmers did not preferred their seed color or size since it has low price and less required by consumers. This is due to the fact that seed was either shriveled due to late maturing type or red colored seed e.g. *Hoggana* and *Alidoro* (Tables 9 and 10). Almost all-top ranked high yielder varieties had been selected by farmers' preference ranking, except

Table 11. Average Coefficient Infections (ACI) for the three rusts of bread wheat varieties at Bekoji Negeso and Sero-Anketo.

Variety	Bekoji-Negesso			Sero-Anketo		
	YR	LR	SR	YR	LR	SR
Honqolo	13.3	0	0	0	0.8	0
Bika	8	0	5.3	0	1.33	14.67
Mandoyu	5.67	0	0	0	1.67	4
Bulluk	1	0	0	0	0.8	1.33
Hiddasse	1	0	1.67	0	2.67	33.33
Ogolcho	0.27	0	0	0	0.67	9.87
Hoggana	0	0	0	0	0	0.53
Hulluka	2.67	0	1.67	0	5.33	6.67
Mekelle-3	0.67	0	1.33	0	0	12
Mekelle-4	8	0	0	0	5.33	8.13
Shorima	2.67	0	0	0	0	0.47
Mekelle-1	0	0	0	0	33.33	13.33
Mekelle-2	3	0	0.8	0	8	20.67
Ga'ambo	6.67	0	0	0	1.33	2.13
Kakaba	5.8	0	11.67	0	0	53.33
Danda'a	2.6	0	2.4	0	0	17.47
Gassay	4.13	0	15.33	0	6	36.67
Alidoro	0	0	0	0	1.33	4
Digelu	1.6	1.07	12.33	0	2.67	46.67
TAY	1	0	0	0	12	4
Sofumar	8	0	0	0	0	5.87
Mada-Wolabu	1.6	0	0	0	0	0.8
Pavon-76	1.73	0	0	0	2.93	2.93
Jefferson	0.27	0	0	0	16.67	43.33
Kingbird	0.93	0	0.67	0	2.67	0.67

YR = yellow/stripe rust; LR = leaf rust; SR = Stem rust.

the variety was affected either by moisture stress or by diseases. This is in line with Belay et al*.* (2006) study in which all farmer-selected genotypes gave higher yields in tef.

Disease reaction of tested bread wheat varieties

Pathogenic fungi are by far the most important and yield limiting of the many disease-causing organisms, which attack cereal crops. Of these, the genera *Puccinia* (rusts), *Ustilago* (smuts), *Tilletia* (bunts), *Erysiphe* (powdery mildews), *Septoria, Alternaria, Helminthosporium, Fusarium* and *Pythium* are the most widespread, regularly occurring and potentially dangerous throughout the world. *Puccinia graminis* (causing stem or black rust), *P. recondita* (causing leaf or brown rust), *P. striiformis* (causing yellow or stripe rust) regularly cause serious losses of wheat throughout the world (Stubbs *et al.,* 1986).

Varieties' disease reaction (Table 11) and their coefficients of infection (CI) (Appendix Table 5) were scored and /or calculated. All the tested varieties at Bekoji station showed resistant type of infection for the three rusts (<20 CI). Similarly, at Sero-Anketo, varieties *Kakaba*, Digelu and Jefferson had moderately susceptible to susceptible reaction, whereas *Gassay* and, *Hiddasse* and *Mekelle-02* had moderately susceptible to moderately resistant types of infection for stem rust, respectively. This result was in contrast with the report of EAAPP (2012) and Haile et al. (2013) that found that *Digelu* and *Danda'a* were preferred varieties by farmers in East Hararge, Arsi and Tigray due to higher resistance to yellow rust and stem rust.

Some varieties showed immune (resistant) type of infection in one location and moderately susceptible type in other location as in Jefferson, *Ogolcho* and *Mekelle-04* for stem rust. This may be due to the presence of stem rust race in one location but not in other location. Roelf et al*.* (1992) reported that, inoculum build-up difference or the environment may favor the development of the stem rust and this disparity may be mainly associated with prevailing specific environmental conditions especially rainfall amount and pattern and temperature. Leaf rust at

Bekoji-Negesso and yellow rust at Sero-Anketo were not observed except on *Digelu*. *Digelu* had been resistant and widely grown variety but it became susceptible to rusts. Pathogens distribution may be affected by different factors and varieties may lose their resistance to rusts at any time due to different reasons, genetic or environmental factors, and therefore, frequent survey on rusts and developing resistant varieties has been important to increase resistance varietal diversity for sustainable quantity and quality wheat production.

Conclusions

Farmers adopt varieties if they provide additional benefits to them such as better productivity, yield stability, increased market value, and increased quality. Based on measured traits (grain yield and rusts resistance) and farmers' preference (field performance and market value) ranking: Bika, Bulluk and TAY for Bekoji (Bekoji-Negesso) and Mekelle-4, Ogolcho and TAY for Iteya (Sero-Anketo) are recommended with their full production packages including pesticide usage for moderately susceptible varieties for rusts, as these varieties also had better protein content. For plant breeders, it may be difficult to predict which traits or trait combinations are of prime importance for a particular target group of farmers. Therefore, future breeding program should include the participation of farmers' and their selection preferences early during varietal development, as participatory plant breeding, and adaptation program for cost effective and fast track delivery of new and existed technologies to particular target group of farmers. Development of appropriate crop production technologies requires a thorough understanding of site-specific problems and farmers need. Therefore, participation of farmers in early breeding program could be one of the approaches as to identify the best variety for specific location.

CONFLICT OF INTERESTS

The authors had not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors thank the Ethiopian Institute of Agricultural research (EIAR) for granting a scholarship to the first author.

ABBREVIATIONS

EAAPP, Eastern African Agricultural Productivity Programme; **EIAR,** Ethiopian Institute of Agricultural Research; **GxE,** genotype by environment; **IRRI,** International Rice Research Institute; **KARC,** Kulumsa Agricultural Research Center; **LSD,** least significant difference.

REFERENCES

Alebachew H (2012). Participatory and performance evaluation of improved bread wheat (*Triticum aestivum* L.) varieties in degua Tibien and ofla woredas of tigray region, Ethiopia M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.

Asaye D, Tadesse D, Getachew A (2014). Participatory varietal selection of bread wheat (*Triticum aestivum* L.) genotypes at Marwold Kebele, Womberma Woreda, West Gojam, Ethiopia. African Journal of Agricultural Research, 9(3):327-333

Assefa T, Abebe G, Fininsa C, Tesso B, Al-Tawaha ARM (2005). Participatory Bean Breeding with Women and Small Holder Farmers in Eastern Ethiopia. World Journal of Agricultural Sciences, 1(1):28-35.

Bekele HK, Verkuijl H, Mwangi W, Tanner D (2000) Adoption of improved wheat technologies in Adaba and Dodola *woredas* of the Bale Highlands, Ethiopia. CIMMYT, Mexico and EARO, Ethiopia, P. 26.

Belay G, Tefera H, Metaferia G, Jarra D, Tadesse T (2006). Participatory variety selection in the Ethiopian cereal tef *[Eragrostis tef* (Zucc.)Trotter]. Experimental Agriculture, 42:91-101

Bellon MR, Reeves J (2002). Quantitative Analysis of Data from Participatory Methods in Plant Breeding. Agricultural Economics, 103:233-244.

Bewley JD, Bradford K, Henk J, Hilhorst H, Nonogaki H (2013). Seeds: Physiology of Development, Germination and Dormancy, 3rd Edition. Springer Science + Business Media, Springer New York Heidelberg Dordrecht, London.

Boef WS, Thijssen MH (2006). Participatory tools working with crops, varieties and seeds. A guide for professionals applying participatory approaches in agro biodiversity management, plant breeding and seed sector development Wageningen, Wageningen International, P. 29.

Boef WS, Ogliari JB (2008). Participatory crop improvement and informal seed Supply. *In*: Thijssen, M.H., Bishaw, Z., Beshir, A. and Boef, W.S. Farmers, seeds and varieties: Supporting informal seed supply in Ethiopia, Wageningen International, pp. 177-185.

Ceccarelli S, Grando S, Booth RH (1996). International breeding programmes and resource-poor farmers: Crop improvement in difficult environments. *In*: Eyzaguirre, P. and M. Iwanaga, (eds), Participatory plant breeding. Proceeding of a Workshop on Participatory Plant Breeding, 26-29 July 1995, Wageningen, The Netherlands. IPGRI, Italy pp. 99-116.

Ceccarelli S (2012). Plant breeding with farmers – A technical manual. International Center for Agricultural Research in the Dry Areas. http://www.growseed.org/Salvatore.pdf

Chung OK (1986). Lipid-protein interactions in wheat flour, dough, gluten and protein fractions. Cereal Foods World, 31:242-256.

Daniel T, Zenebe G, Asrat A (2014). Participatory on Farm Evaluation of Improved Maize Varieties in Chilga District of North Western Ethiopia. International Journal of Agriculture and Forestry, 4(5):402-407.

Dawit A (2010). Seed system potential in Ethiopia: Constraints and opportunities for enhancing the seed sector; EIAR, IFPRI, P 41.

Eastern African Agricultural Productivity Programme (EAAPP) (2012). Enhancing adoption of rust tolerant wheat varieties: Experience of EAAPP in Ethiopia.Ethiopian Institute of Agricultural Research Centre (EIAR), Addis Ababa, Ethiopia.

Food and Agricultural Organization Statistics (FAOStat) (2015). Agricultural production statistics. (http://www.fao.org/faostat) Accessed on 08 November 2016).

Fekadu G (2013). Assessment of Farmers' Criteria for Common Bean Variety Selection: The case of Umbullo watershed in Sidama zone of the southern Region of Ethiopia. Ethiopia e-Journal for Research and innovation Foresight 5(2):4-13.

Finney KF, Barmore MD (1984). Loaf volume and protein content of hard winter and spring wheats. Cereal Chemistry, 25:291-312.

Guush B (2011). Food grain consumption and calorie intake pattern in

Ethiopia, ESSP II working paper 23 IFPRI/EDRI.
IRRI (2006). Rice Breeding Course. www.knowledgebank.irri.org/ricebreedingcourse/ Accessed on 2016
Joshi A, Witcombe JR (1996). Farmer participatory crop improvement.II. Participatory Varietal Selection: a case study in India. Experimental Agriculture, 32:461-477.
Kassa G, Kassahun Z, Amsal T, Girma T (2003). Farmer participatory evaluation of bread wheat varieties and its impact on adoption of technology in West Shewa Zone of Ethiopia. Ethiopian Agricultural Research Institute, Addis Ababa, Ethiopia, 47:46.
Mekbib F (1997). Farmer participation in common bean genotype evaluation: The case of eastern Ethiopia. Experimental Agriculture, 33:399-408.
Mekonen H (2011). Performance and Farmers' Evaluation of Released Common Bean (*Phaseolus Vulgaris* L.) Varieties in Dawro Zone, South Western Ethiopia M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.
Molla F, Tsedalu J (2012). Participatory on Farm Evaluation and Selection of Improved Bread Wheat Varieties in Vertisol Areas of North Western Ethiopia. American-Eurasian Journal of Agronomy, 5(1):06-09.
Mulatu E, Zeleke H (2002). Farmers' highland maize (*Zea mays* L.) selection criteria: Implication for maize breeding for the Hararghe highlands of eastern Ethiopia. Euphytica, 127:11-30.
Roelf AP, Singh RP, Saari EE (1992). Rust Disease of wheat: Concept and Methods of Disease Management. CIMMYT, Mexico, DF., P. 81.
Statistical Analysis System (SAS) (2002). Version 9.0.SAS Institute Inc., Cary, NC, USA.
Shewry PR (2007). Improving the protein content and composition of cereal grain. Journal of Cereal Science 46:239-250.
Simmonds NW (1995). The relation between yield and protein in cereal grain. Journal of the Science of Food and Agriculture, 67(3):309-315.
Stone PJ, Savin R (1999). Grain quality and its physiological determinants. *In*: Satorre, E.H. and Slafer, G.A. (Eds.), *Wheat:* Ecology and Physiology of Yield Determination. Binghamton, NY: Food Products Press. pp. 85-120.
Stubbs RW, Prescott JM, Saari EE, Dubin HJ (1986). Cereal Disease Methodology Manual: The Research Institute for Plant Protection (IPO), Wageningen, the Netherlands, and the International Maize and Wheat Improvement Center (CIMMYT), Mexico.
Tafere M, Tadesse D, Yigzaw D (2012). Participatory varietal selection of faba bean (*Vicia faba* L.) for yield and yield components in Dabat district, Ethiopia. Wudpecker Journal of Agricultural Research 1(7):270-274.
Vogel KP, Johnson VA, Mattern PJ (1978). Protein and lysine contents of endosperm and bran of the parents and progenies of crosses of common wheat. Crop Science, 18:751-754.
Von Braun J, Derek B, Chartres C, Tom L, Norah O, Jeff W (2010). A Draft Strategy and Results Framework for the CGIAR. CGIAR, The World Bank, Washington D.C.
Witcombe JR, Joshi A, Joshi KD, Sthapit BR (1996). Farmers participatory crop improvement. I. varietal selection and breeding methods and their impacts on biodiversity. Experimental Agriculture, 32:445-460.
Witcombe JR, Virk DS (1997). New directions for public sector variety testing. In: Tripp, R. (ed.). New Seed and Old Laws. Regulatory reform and the diversification of national seed systems. ITP on behalf of Overseas Development Institute. p. 59-87
Wrigley WC, Bekes F (2001). Processing Quality Requirements for wheat and other cereal Grains. *In*: Roberto L., Benech-Arnold and Rodolfo A. Sánchez (eds*),* Handbook of seed Physiology.The Haworth Press,Inc. NewYork, London, Oxford. pp. 368-369.
Yazici N, Bilir N (2017). Aspectual Fertility Variation and Its Effect on Gene Diversity of Seeds in Natural Stands of Taurus Cedar (*Cedrus libani* A. Rich.). International Journal of Genomics, pp. 1-5.
Zerihun J, Amsalu A, Grando S (2012). Participatory Barley Variety Selection and Farmers' Selection Criteria in the Bale Highlands of Southeastern Ethiopia. Science, Technology and Arts Research Journal, 1(2):01-11.
Zewdie B (2004). Wheat and Barley Seed Systems in Ethiopia and Syria. PhD Dissertation, Wageningen University, the Netherlands, pp. 383.

APPENDICES

Appendix Table 1. Mean squares from analysis of variance for grain protein content and grain yield of the tested twenty-five bread wheat varieties at Sero-Anketo.and Bekoji-Negesso.

Source of variance	DF	Mean squares			
		Sero-Ankato		Bekoji-Negesso	
		Protein	GYLD	Protein	GYLD
Replications	2	2.15**	82815^{ns}	1.84**	336270**
Blocks within replications (Adj.)	12	0.65**	74753^{ns}	0.51^{ns}	87750^{ns}
Treatments (Unadj.)	24	1.36**	840820**	0.90**	1632418**
Intra block error	36	0.21	73475	0.19	58277
Treatment(Adj.)	24	1.38**	796077.18**	0.92**	1558562.62**

*Significant at 5% probability level; **highly significant at 1% probability level, ^{ns}, non-significant at 5% probability level; GYLD, Grain yield; DF, Degree of freedom; Protien, Grain protein content.

Appendix Table 2. Mean square from combined analysis of variance for grain protein content and grain yield of the tested twenty-five bread wheat varieties at locations.

Source	DF	Mean square	
		Protein	GYLD
Loc	1	284**	110215347**
rep(loc)	2	3.98**	42748.3^{ns}
blk(rep)	12	0.66**	66600.5^{ns}
Treatment	24	1.39**	829634.1**
Loc x treatment	24	0.70**	1529648.6**
Blk x treatmnt(rep)	36	0.24^{ns}	71531.4^{ns}
Error	48	0.24	69141.2

*Significant at 5% probability level; **highly significant at 1% probability level; ns, non- significant at 5% probability level; GYLD, Grain yield; DF, Degree of freedom; Protien, Grain protein content.

Appendix Table 3. Pair wise ranking of 25 bread wheat varieties by traders and consumers at Bekoji-Negesso.

var≈	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	X																								
2	2	X																							
3	3	2	X																						
4	4	2	4	X																					

Appendix Table 3. Contd.

5	5	2	5	5	X																				
6	6	2	3	4	5	X																			
7	1	2	3	4	5	6	X																		
8	1	2	3	4	5	6	8	x																	
9	1	2	3	4	5	6	9	8	X																
10	10	2	10	4	5	6	10	10	10	X															
11	11	2	11	11	5	11	11	11	11	11	X														
12	12	2	12	4	5	12	12	12	12	10	11	X													
13	13	2	13	4	5	13	13	13	13	13	11	13	X												
14	14	2	3	4	5	6	14	14	14	14	11	14	14	X											
15	15	2	15	15	5	15	15	15	15	15	11	15	15	15	X										
16	16	16	16	16	5	16	16	16	16	16	16	16	16	16	16	x									
17	17	2	3	4	5	6	17	17	17	10	11	12	17	14	15	16	x								
18	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	x							
19	19	2	19	19	5	19	19	19	19	19	11	12	13	14	15	16	17	19	X						
20	20	2	3	20	5	20	20	20	20	20	11	20	20	20	15	16	20	20	20	X					
21	21	2	21	4	5	6	21	8	4	10	11	12	13	14	15	16	17	21	19	20	X				
22	22	2	22	4	5	22	22	22	22	10	11	12	13	22	15	16	17	22	22	20	22	x			
23	23	2	3	4	5	6	23	8	23	10	11	12	13	14	15	16	17	23	19	20	21	22	x		
24	1	2	3	4	5	6	24	8	9	10	11	12	13	14	15	16	17	24	19	20	21	22	23	x	
25	25	2	25	25	5	25	25	25	25	25	25	25	25	25	16	25	25	25	25	25	25	25	25	25	x
T≈	5	23	11	17	23	11	1	6	3	12	20	13	14	13	19	23	11	0	11	17	7	12	5	2	21
R≈	20	1	14	7	1	14	24	19	22	12	5	10	9	10	6	1	14	25	14	7	18	12	20	23	4

var≈ = varieties; T≈ =Total scores; R≈ = Ranks. The bold numbers represents the 25 bread wheat varieties: 1, *Honkolo*; 2, *Bika*; 3, *Mandoyu*;4, *Bulluk*; 5, *Hiddasse*; 6, *Ogolcho*; 7, *Hoggana*; 8, *Hulluka*; 9, *Mekelle*, 03; 10, *Mekelle*, 4; 11, *Shorima*; 12, *Mekelle-01*; 13, *Mekelle-02*; 14, *Ga'ambo*; 15, *Kakaba*; 16, *Danda'a*; 17, *Gassay*; 18, *Alidoro*; 19, *Digelu*; 20, *TAY*; 21, *Sofumar*; 22, *Medawelabu*; 23, *Pavon*, 76; 24, *Jefferson*; 25, *Kingbird*.

Appendix Table 4. Pair wise ranking of 25 bread wheat varieties by traders and consumers at Sero-Anketo (2015).

var≈	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	X																								
2	2	X																							
3	3	2	X																						
4	4	2	4	X																					
5	5	5	5	5	X																				
6	6	6	6	6	5	X																			
7	1	2	3	4	5	6	X																		

Appendix Table 4. Contd.

8	1	2	3	4	5	6	8	x																	
9	1	2	3	4	5	6	9	8	x																
10	10	10	10	10	5	6	10	10	10	X															
11	11	2	11	4	5	11	11	11	11	10	X														
12	12	2	12	12	5	12	12	12	12	10	12	X													
13	13	13	13	13	13	13	13	13	13	13	13	13	X												
14	4	2	14	14	5	14	14	14	14	14	14	14	13	X											
15	15	15	15	15	15	15	15	15	15	15	15	15	15	13	x										
16	16	2	16	16	5	6	16	16	16	10	11	12	13	14	15	X									
17	17	2	3	17	5	6	17	17	17	10	11	12	13	14	15	17	X								
18	1	2	3	4	5	6	18	8	9	10	11	12	13	14	15	16	17	x							
19	1	2	3	4	5	6	19	8	19	10	19	12	13	14	15	16	17	19	X						
20	20	20	20	20	5	6	20	20	20	20	20	20	13	14	15	20	20	20	20	x					
21	21	2	3	21	5	6	21	21	21	10	11	12	13	14	15	21	17	21	21	21	X				
22	22	22	22	22	5	22	22	22	22	22	22	22	13	22	22	22	22	22	22	22	22	x			
23	23	2	3	23	5	23	22	23	23	10	11	12	13	23	15	23	17	23	23	20	21	22	x		
24	1	2	3	4	5	6	24	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	x	
25	25	25	25	25	5	25	25	25	25	25	25	12	13	14	15	16	25	25	25	20	21	22	25	25	x
T≈	6	16	10	9	22	15	0	5	3	16	13	15	23	18	23	10	11	2	5	17	12	22	11	1	15
R≈	19	7	16	18	3	9	25	20	22	7	12	9	1	5	1	16	14	23	20	6	13	3	14	24	9

var≈ = varieties; T≈ = Total scores; R≈ = Ranks, The bold numbers represents the 25 bread wheat varieties: 1, *Honkolo*; 2, *Bika*; 3, *Mandoyu*;4, *Bulluk*; 5, *Hiddasse*; 6, *Ogolcho*; 7, *Hoggana*; 8, *Hulluka*; 9, *Mekelle*, 03; 10, *Mekelle*, 4; 11, *Shorima*; 12, *Mekelle-01*; 13, *Mekelle-02*; 14, *Ga'ambo*; 15, *Kakaba*; 16, *Danda'a*; 17, *Gassay*; 18, *Alidoro*; 19, *Digelu*; 20, *TAY*; 21, *Sofumar*; 22, *Medawelabu*; 23, *Pavon*, 76; 24, *Jefferson*; 25, *Kingbird*.

Appendix Table 5. Severity percentages and field responses of the tested bread wheat varieties to the three rusts.

Variety	Severity percentage and response (reaction)					
	Bekoji-Negesso			Sero-Anketo		
	YR	LR	SR	YR	LR	SR
Honqolo	10ms-20ms	0	0	0	0-tms	0
Bika	10ms	0	0-10ms	0	0-5msmr	5msmr-30msmr
Mandoyu	5m-10ms	0	0	0	0-5sms	0-10msmr
Bulluk	0-5m	0	0	0	0-tms	0-5mss
Hiddasse	0-5m	0	0-5s	0	0-10sms	0-60s
Ogolcho	0-tmr	0	0	0	0-5mrms	tms-30mss
Hoggana	0	0	0	0	0	0-tms
Hulluka	5mr-5ms	0	0-5s	0	0-20mss	5msmr-15msmr
Mekelle-3	0-5mr	0	0-5ms	0	0	5msmr-20msmr
Mekelle-4	10m-20m	0	0	0	0-20mss	tr-20msmr
Shorima	0-5ms	0	0	0	0	0-5mrms
Mekelle-1	0	0	0	0	0-50s	10msmr-20sms
Mekelle-2	0-10m	0	0-tms	0	0-30sms	20msmr-30sms
Ga'ambo	10m-10ms	0	0	0	0-5ms	tmr-5mss
Kakaba	tms-15m	0	0-20mss	0	0	40s-70s
Danda'a	tmr-5ms	0	0-5ms	0	0	tms-40s
Gassay	tms-10m	0	10ms-30sms	0	0-10sms	30sms-50s
Alidoro	0	0	0	0	0-tms	0-10msmr
Digelu	0-tms	0-tms	0-30sms	0	0-10sms	40s-50s
TAY	0-5m	0	0	0	0-20sms	0-10msmr
Sofumar	5msmr-10sms	0	0	0	0	tmsmr-20mss
Mada-Wolabu	0-5ms	0	0	0	0	0-tms
Pavon-76	tmr-5mr	0	0	0	0-10ms	tmr-10msmr
Jefferson	0-tmr	0	0	0	0-50s	40s-50s
Kingbird	0-5mr	0	0-ts	0	0-10msmr	0-tmsmr

YR, Yellow/stripe rust; LR, leaf rust; SR, stem rust.

Vol. 13(44), pp. 2499-2509, 1 November, 2018
DOI: 10.5897/AJAR2018.13398
Article Number: 4DD766259101
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Competitiveness of Brazilian soybean exports

Maristela Franchetti de Paula[1], Humberto Angelo[2], Anadalvo Juazeiro Santos[3], Alexandre Nascimento de Almeida[2], Pedro Guilherme de Andrade Vasconcelos[2*], Ari Schwans[1], Eder Pereira Miguel[2] and Ademir Juracy Fanfa Ribas[1]

[1]Department of Administration, State University of West Centre, Guarapuava, PR, Brazil.
[2]Department of Forestry Engineering, University of Brasilia, Campus Darcy Ribeiro, Brasilia, DF, Brazil.
[3]Department of Rural Economy, Federal University of Paraná, Curitiba, PR, Brazil.

Received 16 July, 2018; Accepted 18 September, 2018

The objective of this article was to analyze the indicators of competitiveness in the foreign trade of Brazilian soybean from the year 2004 to 2014. The problem under study deals with the competitiveness of this commodity in the international market. The applied methodology initially used the descriptive statistics, seeking to demonstrate through tables and graphs the evolution of the soybean exports in the international market. The data of the largest exporters worldwide were used to relate the volume (ton) and the value (US$) of this product. The economic indicators used to verify competitiveness were the Constant Market Share model and the Revealed Comparative Advantage Index. The main exporting countries are the United States, Brazil, and Argentina, respectively. The results indicated that the Brazilian soybean exports in the analyzed period have Revealed Comparative Advantages in comparison to other exporters. The Constant Market Share indicated that the main source of growth for soybean was the growth of world trade. It demonstrates that Brazil is strongly influenced by soybean's international market price. It is concluded that Brazil has competitiveness in the market of soybean, presenting high standards of efficiency. Brazil also makes use of similar resources to those of leading producers, and has the potential to increase its participation through its technology, productivity and territorial capacity in order to increase production.

Key words: Competitiveness, constant market share, soybean.

INTRODUCTION

The soybean has been cultivated for five thousand years, and its origin is attributed to the central plains of China near lakes and rivers. About 3000 years ago, it spread throughout Asia and was used for human consumption. In the early twentieth century, this crop cultivation started in the United States and then spread into commercial cultivars worldwide (Sanches et al., 2004).

In Brazil, the grain arrived in 1882 in the state of Bahia, but its official introduction was in the state of Rio Grande do Sul. Since the 1970s, soybean production has become important for the agribusiness sector. This is confirmed by the increase in cultivated areas, mainly by increasing productivity using new technologies, improving the management as well as the efficiency of producers.

*Corresponding author. E-mail: pedroguilherme.av@gmail.com.

This process has increased the participation of soybean agro-industry chain in the economy, making it essential for income growth, employment and export currencies (Silva et al., 2011).

Caro et al. (2018) argues that soy is responsible for the emergence of Brazilian commercial agriculture, accelerating the mechanization of crops, modernizing transportation, and expanding the agricultural frontier. Soybeans' sector also collaborated for the emergence of new techniques that translated in increasing production of other crops, and it sponsored the development of poultry and swine breeding in Brazil.

Oliveira (2014) confirms this position, stating that the modernization process initiated in 1990 with the opening of the Brazilian economy and the introduction of new technologies allowed producers increase their productivity. These factors were decisive for Brazil to expand its production and become the second largest soybean producer in the world.

In the national context, the soy is economically inserted as one of the main crops produced. Data from the Ministry of Agriculture, Livestock and Food Supply (MAPA, 2016) confirms that soybeans are the fastest growing crop in the last decades and occupies 49% of the grain planting areas in Brazil. According to data from the National Supply Company - CONAB (2015), in 2013/2014 harvest, about 86.12 million tons of soy were produced in the country, accounting for 44.5% of all Brazilian grain production in the same harvest. The 2015 harvest reached 97000 tons, representing 48% of the 202.23 million tons of grains produced by the country.

The center-west region is the production leader, with approximately 44000 tons. In this region, the state of Mato Grosso is the largest producer with 28000 tons. The south region also established itself as the second largest producer, with approximately 35000 tons in the harvest of 2015. The state of Paraná is the largest producer with 17000 tons (Raucci et al., 2015). According to the Agribusiness Projections Report of the Ministry of Agriculture, production could reach 117.8 million tons in the 2023/2024 harvest.

In the international context, in the last 50 years, the world production of soybean multiplied by ten and reached 269 million tons. The Food and Agriculture Organization (FAO, 2015a) predicts that by 2050, production will almost double, reaching 515 million tons. In the period from 2000 to 2009, China doubled the consumption of soybeans; 41 million tons were imported and the projections indicate a 59% increase by 2021 to 2022.

Brazil has intensified its trade relations with China, with the soybean being the highlight product. Together, China and the European Union are responsible for approximately 80% of the Brazilian exports of the soybean complex. Brazil is considered an important player and is currently considered the second largest producer and exporter of soybeans in the world (FAO, 2015b).

The prospects for the upcoming decades are favorable. Brazil has a dynamic structure capable of absorbing the growing demand for soybeans. Due to the importance of soybean export growth in the Brazilian economy and with a rising trend, the present study aims to analyze the soybean competitiveness indicators of the world main exporters: The United States, Brazil, and Argentina, from 2004 to 2014.

From these results, several other aspects can be examined, such as more advanced studies on the identification of factors related to the competitiveness of the soybean complex, analyzing Brazilian exports in comparison to the exports of the United States and Argentina, which are the main competitors of Brazil in this market.

MATERIALS AND METHODS

The current delineates the exports of soybeans from Brazil, United States, and Argentina in the period from 2004 to 2014. For the development of the study, a database of secondary data was used. The collected information was tabulated from several sources such as:

(a) UN COMTRADE, United Nations Commodity Trade Statistics;
(b) FAO, Food and Agriculture Organization of the United Nations;
(c) ALICEWEB, Analysis System of Foreign Trade Information;
(d) IBGE, The Brazilian Institute of Geography and Statistics;
(e) CONAB, National Company of Supply.

The period from 2004 to 2014 was evaluated as a time series, applying the methodology of descriptive statistics to demonstrate the evolution of exports in the international soybean market. Data were studied referring to the international soybean market as Brazil, the United States and Argentina.

Exploratory analysis of the major exporting countries and the main soybean importing countries, Brazil, the United States and Argentina, were made by the relative share of each, from 2004 to 2014. It was calculated by the mathematical expression (Parapinski, 2012):

$$P\% = \left(\frac{E_{Pi}}{E_T} \right) * 100 \tag{1}$$

where P %= relative share of a country i; E_{Pi} = soybean exports of a country i; E_T = world soybean exports.

Descriptive statistics tools, such as tables and graphs, were used for these three exporting countries where it was possible to have an overview of the variation of values and participation of the main soybean exporting countries.

Data from 2004 to 2014 annual time series of the soybean commodity, collected in the UNCOMTRADE database, related to volume (tons) and value (US$) of US, Brazilian, Argentine and world exports. These data are expressed in millions of dollars and were deflated in the year 2014, based on the United States Consumer Price Index (CPI).

The analysis of the competitiveness of the main world exporters was carried out using the methodologies of Constant Market Share (CMS) and the Revealed Comparative Advantage Index (RCA).

Constant Market Share (CMS)

The widely disseminated model by Richardson (1971) has been used in studies on growth and performance in foreign trade as well as to analyze the factors that exert influence on a nation's exports over a time horizon.

According to Coronel et al. (2008), the work based on CMS models aims to evaluate the participation of a country or region in the global or regional flow of trade and to disaggregate growth trends in exports and/or imports according to their determinants. In this sense, the CMS model was used to examine the determination of the factors that contributed to the performance of the exports of a country or economic bloc in a given period.

In the CMS method, variations in world market share can be dissected into export growth sources and the elements responsible for this behavior can identified. According to Horta (1983), these effects are expressed in:

(1) The growth effect of world trade: growth in exports results from world growth;
(2) The destination exports effect: represents the gains or losses in terms of growth rate, since the country exports to markets that grew at rates higher or lower than the average observed for all countries;
(3) Composition effect of tariff: greater concentration on the export agenda of products whose world demands grow faster. This effect makes it possible to identify the gains or losses in terms of the growth rate due to the concentration of tariff in products that presented higher growth rates (or lower than the average of all products);
(4) Competitive effect: It is determined on a residual basis and reflects the difference between the actual growth of exports and what would have happened to the country's exports if the share of each good had been maintained for the buyer's market. It means that an economy is competitive in the production of a given product when it can at least match the efficiency standards in the rest of the world, regarding the use of resources and the quality of the goods.

The basic assumption of the model is that each country or bloc keeps its share of the world trade constant. If there is a change in this share, it must be implicit in the model, and its performance is attributed to competitiveness, associated with relative prices (Leamer and Stern, 1970).

According to Ferraz et al. (1995), constant market share is the main indicator of competitiveness and is defined as the participation of a product, company or nation in a given market, and is expressed by:

$$\sum V'_{ij} - V_{ij} = \sum rV_j + \sum_i \sum_j (r_{ij} - r_i) V_j + \sum (V'_j - V_j - r_j V_j) \quad (2)$$

where V 'ij = monetary value of exports of merchandise i (soybean) from the country in focus to market j, in period 2; V ij = monetary value of exports of merchandise i (soybean) from the country in focus to market j, in period 1; V 'ij - V ij = effective growth of the value of the country's soy exports to market j; and r = percentage growth of the value of world exports of soybeans in period 1 to period 2.

The analysis based on the CMS model has its importance and interest, as it determines the weight of each effect on the exports of the country in question and shows the extent to which these are directed towards commodities and/or markets with greater potential for expansion. In this sense, the results can indicate alternative actions and signal distribution paths for exports, in order to pursue more dynamic "market-shares".

Also, Machado et al. (2006) state that this model allows one determines the factors that influence the performance of a country's exports over the years. The favorable or unfavorable growth of the export sector is attributed to the structure of the country's exports and its competitiveness. The main advantage of this method is to allow the analysis, by components and behavior, of the product in the destination market.

As a result, the CMS model has been used in several studies to analyze the determination of factors that contribute to the performance of a country's exports in a given period. Such studies include Carvalho (1995), Figueiredo et al. (2004), Machado et al. (2006), Coronel et al. (2008), and Silva et al. (2011).

In this present study, the CMS calculation was performed from the year 2004 to 2014, studying the three main exporters, which represent approximately 77% of the world's exports. It was possible to verify the effect of the world's soybean market growth, the effect of the destination of the exports and the effect of the competitiveness of the world soybean market in the period, excluding the tariff factor as it is an analysis of a single product.

Revealed comparative advantage index (RCA)

The main definition of the RCA was conceptualized by Balassa (1965), cited by Fajnzylber et al. (1993) on the assumption that world trade among different nations is adjusted according to their comparative advantages.

The RCA measures the structure of exports while considering the export performance of a given product and the country's commercial performance on the world market. Thus, the comparative advantage can be used to select the products with potential gains of trade. For its calculation, the mathematical expression used was (Oliveira, 2005; Pais et al., 2008):

$$RCA_j = \frac{(X_{ij} / X_i)}{(X_{wj} / X_w)} \quad (3)$$

where Xij = value of Brazilian soybean exports; Xi = total value of Brazilian exports; Xwj = total value of world exports of soybeans; Xw = total value of world exports; i = Brazilian exports; w = world exports; and j = soybean.

The RCA was qualified according to the criteria presented by Pais et al. (2008), being:

(a) RCA j > 1 = the country has a comparative advantage for soybean exports; and
(b) RCA j < 1 = the country has a comparative disadvantage for soybean exports.

RESULTS

Global soybean production is concentrated in just three countries: The United States, Brazil and Argentina, totaling 82%. In addition, the other four countries that stand out in the world production are: China, India, Paraguay and Canada. Together, these seven countries represent about 95% of the world's oilseed production according to data from the United States Department of Agriculture (USDA, 2015). The world soybean crop of 2014/2015 was 317253 million tons, the United States share was 108.014 million tons, with a productivity of

Table 1. Total world soy exports in the period of 2004-2014.

Year	Quantity (Ton)	Actual Amount (US$ million)
2004	57 454 434	19 445 847
2005	65 924 837	18 971 515
2006	67 782 565	18 905 248
2007	74 163 760	26 099 991
2008	79 971 937	38 621 250
2009	81 278 119	36 459 550
2010	97 367 137	43 121 572
2011	90 943 573	48 094 679
2012	96 472 609	54 839 990
2013	106 505 216	58 377 280
2014	109 219 501	59 005 889
Total	927 083 692	421 942 810

Source: UN COMTRADE (2015).

3.213 kg/ha. Brazil, the second largest producer, participated in producing 95.070 million tons, with a production of 3.011 kg/ha (CONAB, 2015).

Soy is one of the most widespread crops in the world. Despite its great economic importance in the world market, the appreciation of soybeans is limited to a few countries. China and the European Union combined account for approximately 75.6% of world imports, according to USDA data from the 2014/2015 harvest. China participates with almost 65%, demonstrating its relevance in the world oilseed market. Thus, any oscillation in the Chinese economy that compromises the flow of its demand for soybeans may jeopardize the global supply and demand of the commodity (USDA, 2015).

World exports totaled more than 927 million tons and approximately 432 billion dollars between year 2004 and 2014 (Table 1). They showed a constant evolution, from 57 million tons in 2004 to approximately 110 million tons in 2014.

World soybean exports have been growing in recent years, in line with the increasing world supply and consumption of oilseed. Around 40% of the world production of the crop, during the 2013/2014 harvest, was exported according to data from the Department of Agriculture of the United States (USDA, 2015). Despite the growth, the average price showed oscillations due to world supply and demand, but it has remained relatively constant since 2012 as shown in Figure 1.

The main exporters of value and quantity are: the United States, Brazil, and Argentina. In value (US$), the United States stands out as the largest exporter with 38% of total world exports of soybeans, followed by Brazil with 30%, and Argentina with only 9%. The other countries participate with 23%.

Figures 2 and 3 show data on quantity (kg) and value (US$) from 2004 to 2014. They show the evolution of the main world exporters. Brazil assumed the position of largest exporter in terms of quantity (kg) in 2013 and 2014, but in most of the years studied the United States was the world's largest producer and exporter. The data in Table 2 confirm the concentration between the United States, Brazil and Argentina since these three countries account for 87% of the world's soy exports.

The United States is the world's largest producer and exporter, followed by Brazil and Argentina. The United States and Brazil, the main producers and exporters of soybeans, may have an impact on the world supply should any change in the size of the soybean crop occur in these two countries (USDA, 2015).

Figure 2 shows the evolution of exports in quantity from the United States, Brazil and Argentina. Similarities can be seen in the first years, up to 2008, when Argentina suffered a sharp fall due to political and economic problems. During this period, there was an increase in exports from the United States. As of 2009, the United States showed a fall and Argentina an increase in exports. On the other hand, Brazil has been in constant evolution throughout the years, with a slight decline appearing between 2011 and 2012.

Figure 3 shows the evolution of exports in value (US$) of the United States, Brazil and Argentina. Argentina suffered a fall between 2008 and 2009. In 2010, the United States had a fall, followed by a rise in values in 2011. However, in 2012, there was a decrease again. Brazil continues to grow steadily in most years, with a slight decline occurring between 2009 and 2010.

Brazil participated in the international market with a total of 326 million tons from 2004 to 2014. It exports to several countries, and the main are, China, the Netherlands, Spain, Germany, part of Asia (Taiwan and others), and Italy in that order (Table 2).

China is considered the largest partner of Brazil, negotiating more than 190 million tons (Table 2),

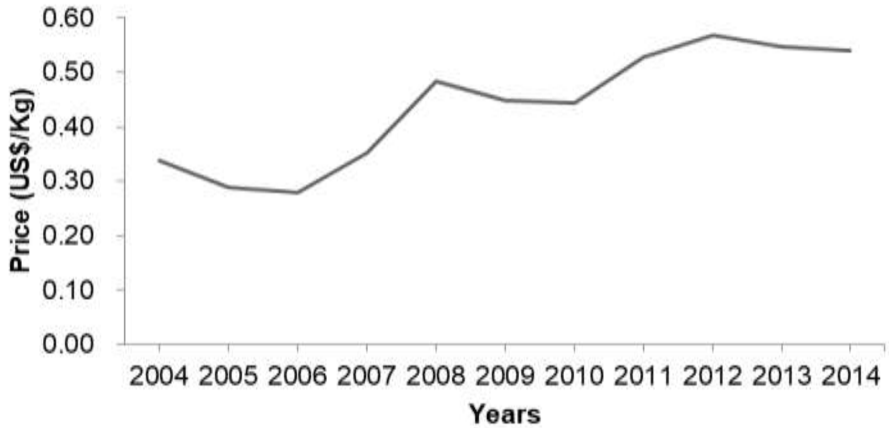

Figure 1. Average price (US$/Kg) of world exports in the period 2004-2014.
Source: UN COMTRADE (2015).

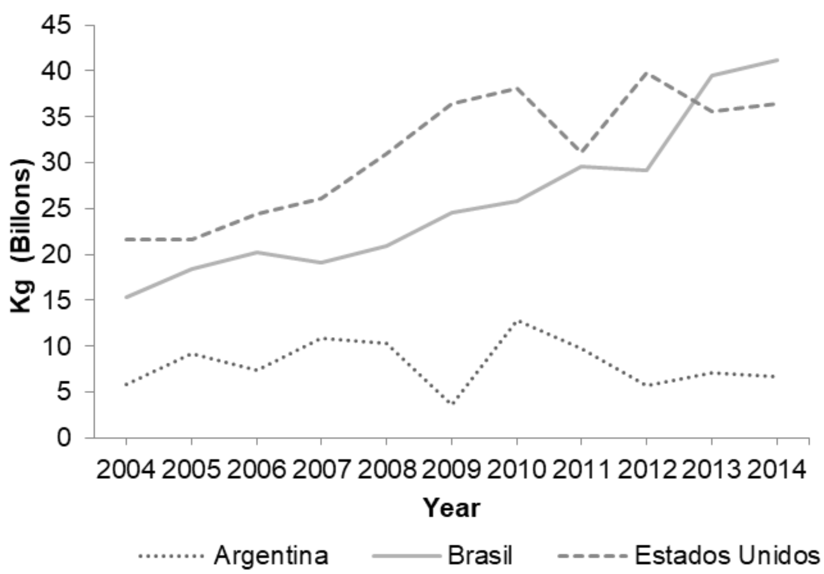

Figure 2. Evolution of soy exports in quantity (kg) in the period of 2004-2014.
Source: UN COMTRADE (2015).

accounting for 40% of soybean imports from this country during the study period. According to the Secretariat of Foreign Trade, China presents itself as the country with the greatest potential for Brazilian agribusiness products given its diversity of imports, growing market and consumption (SECEX, 2013).

In the last ten years, the United States has led soy exports seven times and Brazil three. Brazilian participation in production and exports has increased from 28.49 to 31% (production) and from 32.66 to 40.79% (export). You can see that the country grows above the international average (USDA, 2015).

The United States is the largest soybean producer and exporter in the world. They totaled in their exports approximately 384 million tons in the analyzed period. Exports to China, Mexico, Japan, Indonesia, part of Asia (Taiwan and others) and Germany totaled approximately 310 million tons for these destinations in the analyzed period shown in Table 4. For its main market, China imported approximately 200 million tons, accounting for approximately 42% of soybean imports from this country (Table 3).

Argentina, the third largest producer and exporter, sent approximately 86 million tons to the market in the study period; the value was below Brazil and the United States. It exported to China, Egypt, Thailand, Turkey, Chile, and

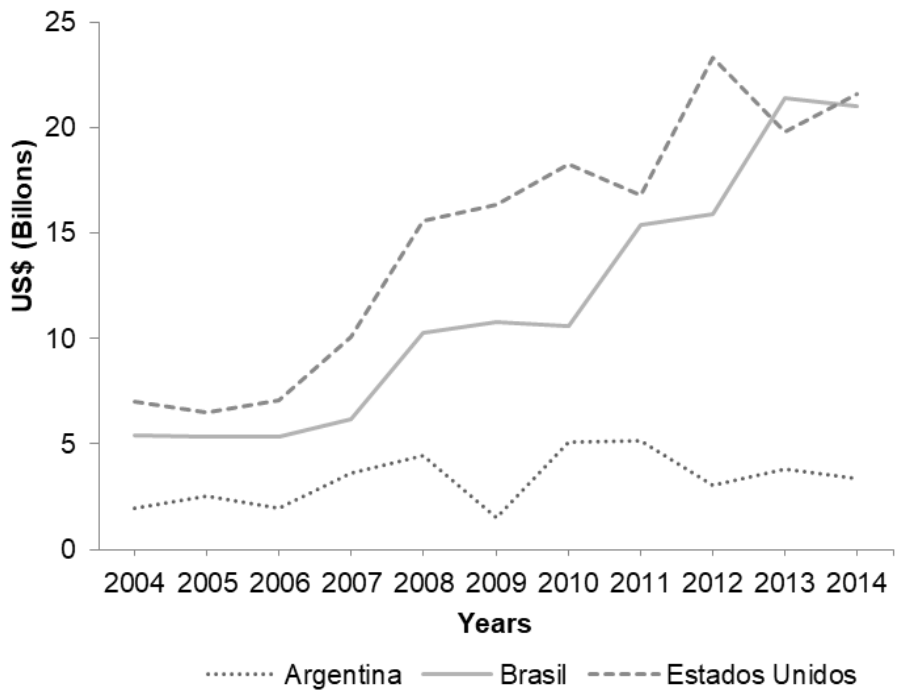

Figure 3. Evolution of soy exports in value (US$) in the period 2004-2014.
Source: UN COMTRADE (2015).

Table 2. Main destinations of soy exports from Brazil in the period 2000 to 2014.

Country	Quantity (Ton)	Nominal Value (US$ million)
China	190 079 887	84 000 582
Netherlands	28 081 702	9 613 445
Spain	23 044 986	9 156 223
Germany	8 359 777	3 115 074
Asia (part)	7 238 303	3 068 991
Italy	7 963 060	2 689 156

Source: UN COMTRADE (2015).

Malaysia (Table 4). Its main market is China, which imported approximately 77 million tons (Table 4), representing approximately 16% of soybean imports from this country in the analyzed period. Table 4 shows Argentina exports data.

Despite some disadvantages regarding the United States, Brazil is currently considered the world's second-largest producer of soybeans. In the 2014/2015 harvest, 31.3 million hectares were cultivated and the Americans 34.31 million hectares. Brazilian production was close to 86 million tons in the 2013/2014 harvest. OECD-FAO (2015) data indicate that soybeans are the most profitable export product for Brazil. Data from the Agribusiness Projections Report of the Ministry of Agriculture estimates that Brazilian production of 117.8 million tons in the 2023/2024 harvest, will generate 22.8 US$ billion in 2024 (OECD/FAO, 2015).

The results show that the period from 2004 to 2014 was characterized by the growth of exports and the prospect of increased demand in the international market. They show that the market demands an increase in the production of the main exporting countries, and for that, efforts in technologies are relevant.

Another factor to note is that the southern hemisphere, due to the availability of areas for future expansion, is expected to be the major soy producer in the world. The main portion of the soybean surplus that will be produced in the world will come from Brazil and Argentina. In the Northern Hemisphere, if there is any expansion of production, this will be much more a result of technological gains than of physical expansion of production (MAPA, 2016).

Table 3. Main destinations of soy exports from the United States for the period 2000 to 2014.

Country	Quantity (Ton)	Nominal Value (US$ million)
China	200 453 764	91 767 227
Mexico	36 863 479	15 234 221
Japan	27 680 653	11 446 891
Indonesia	16 107 650	7 179 442
Asia	16 745 702	7 027 148
Germany	11 956 884	5 092 255

Source: UN COMTRADE (2015).

Table 4. Main destinations of Argentine's soy exports in the period 2000 to 2014.

Country	Quantity (Ton)	Nominal Value (US$ million)
China	77 237 786	29 256 022
Egypt	4 080 233	1 648 159
Thailand	2 717 267	858 231
Turkey	1 807 595	612 216
Chile	1 052 563	337 813
Malaysia	896 530	294 034

Source: UN COMTRADE (2015).

Constant market share (CMS)

Among the studies developed based on the constant market share are those of Grams et al. (2013), which sought to identify the determinants of the growth of exports of the Brazilian automotive industry from 1999 to 2008. In this same context, Fries et al. (2013) analyzed the scenario of the exports of the agribusiness. Ferreira et al. (2013) analyzed the performance of exports of soybeans in grain from 1995 to 2009. Angelo (1998), Coronel et al. (2008) and Almeida (2010) used this indicator in the forest sector. Coelho and Berger (2004) analyzed the behavior of the furniture sector. Valverde et al. (2006) analyzed the performance of Brazilian pulp exports. Noce et al. (2008) researched the international pellet market. Carvalho et al. (2010) examined Brazilian paper exports. Almeida et al. (2010) analyzed the Brazilian and Canadian exports of sawn timber. Parapinski (2012) studied the dynamics of exports of wooden furniture.

The model was widely disseminated by Richardson (1971) and has been used in studies on growth and performance in foreign trade and to investigate the factors influencing a nation's exports over a time horizon.

Using CMS method, the favorable or unfavorable growth of an export sector is assigned to the structure of its exports and competitiveness. The main advantage of this method is the component analysis and the behavior of the product in the destination market (Machado et al., 2006).

According to Carvalho (1995), research and studies based on Constant Market Share models aim to assess the participation of a country or region in the global or regional flow of trade and to disaggregate growth trends in exports and/or imports according to their determinants.

The basic assumption of the model is that each country or block keeps its share in the world trade constant. If there is a change in this part, it must be implicit in the model, its performance attributed to competitiveness and associated with relative prices (Leamer and Stern, 1970).

According to Leamer and Stern (1970), the factors that deprive a country's exports from following the world's average are a concentration of exports in goods whose demand grows more slowly than the average products; exports to stagnant regions; and lack of willingness or conditions that enables the country compete with its suppliers in the international market.

The CMS aims to evaluate the effects and influences on the development of exports of a product in a considered period, in addition to revealing the performance of a firm or country from its main competitors. Through the use of CMS, the favorable or unfavorable growth of the export sector is attributed to the structure of the country's exports and its competitiveness. The main advantage of this method is to allow component analysis and product behavior in the destination market (Valverde et al., 2006).

The increase in exports results in gains for the country, which cannot determine that it is competitive in a given sector of the market alone. Thus, it is necessary to

Table 5. The share of sources of growth in soy exports from 2000 to 2014.

Country	Growth (%)	Destination (%)	Competitiveness (%)	Total (%)
United States	109.93	- 807.68	797.75	100
Brazil	83.28	- 62.85	79.57	100
Argentina	277.97	115.82	- 293.79	100

Table 6. Revealed comparative advantage index (RCA) of Brazilian soybean, 2004-2014.

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
RCA	13.26	13.82	18.09	11.56	11.55	22.74	25.88	24.75	27.84	27.92	30.20

analyze the factors that influence the behavior of exports, to verify the competitiveness of the country in the international market (Machado et al., 2006). Based on this assumption, the constant market share was calculated, which was expressed as a percentage, in that the higher its value, the greater the intensity of the country's participation as an exporter in international trade (Oliveira, 2005). The constant market share was calculated in the period between 2004 and 2014 when a significant increase in soybean exports was observed in comparison with the previous decade, and the main world exporters were evaluated: the United States, Brazil and Argentina (Table 5).

The growth effect of world trade represents the observed growth if the exports of the examined countries evolved at the same rate of growth with world exports. The main soybean exporting countries presented positive percentages in the growth factor (Table 6; Figure 1). Brazil had the lowest value (83.28%), followed by the United States (109.93%); while Argentina was the most expressive country, with 277.97%. In general, the results of this effect demonstrate the existence of a worldwide increase in the soybean trade.

According to Table 5, the growth effect of world trade, which in this period was positive, can be explained by the following factor: a significant increase in grain demand by China, which prioritizes the importation of in natura products, with lower added value as a way of valuing internal processing (Coronel et al., 2008). Another factor that may have contributed to this result was an increase in world exports of soybeans; indicating that, throughout the study period, the largest importers of the product were China and the European Union.

The destination factor provided negative percentage values (Table 6), except for Argentina that presented a positive value. The lowest and closest to the positive was obtained by Brazil (-62.85%), followed by the United States (-807.68%). Argentina presented a positive and expressive value of 277.97%.

The effect of exports represents the gains (or losses) in terms of growth percentage, considering whether the country exports to markets that grow at higher (or lower) rates than those observed in all countries. According to Machado et al. (2006) and Grams et al. (2013), the export effect will be positive if a given country concentrates its exports in markets that have experienced greater dynamism in the period under review, while negative if concentrated in more stagnant regions.

In the present study, negative values (Table 6) indicate that Brazil and the United States are shifting their exports to less dynamic markets, meaning that their exports are concentrated in markets with growth rates lower than the average observed for all countries. The lower negative index of the target effect (Table 6) obtained by Brazil made it possible to infer that Brazil's exports were concentrated in markets with greater dynamism, while the United States concentrated its exports to less dynamic markets.

It is considered that the competitiveness effect reflects the improvements in prices, quality of the product, and reduction of production costs, or in the conditions of investments. Competitiveness can be observed as an effect of supply since it depends on the change in the relative efficiency of the countries in the world market (Machado et al., 2006). In terms of competitiveness, the United States had the highest percentage (Table 3), with 797.75%, followed by Brazil (79.57%).

Residual is attributed to the failure or success of the country in international trade. Argentina presented a negative index (-293.79%), showing that it did not maintain its share in the world market, and its competitiveness effect became negative; indicating the failure of the country to maintain its constant participation. This effect demonstrates that importers tend to substitute the consumption of commodities whose prices were increased by the consumption of those products with relatively lower prices (Grams et al., 2013).

The competitive effect indicates that an economy is competitive in the production of a particular commodity when it can at least match the efficiency standards of resources and quality (Grams et al., 2013). Thus, the results (Table 6) indicate that Brazil presented greater competitiveness in the world soybean market and similar standards of efficiency and resource utilized in the world.

Revealed comparative advantage index (RCA)

The RCA allows the identification of the importance of a given product in the Brazilian export agenda in relation to the world. In the Brazilian forestry and agricultural sector, the RCA was used by several researchers, such as Figueiredo et al. (2004), Ropke and Palmeira (2006), Maia et al. (2008), Coronel et al. (2009), Almeida (2010), etc.

The RCA was analyzed in accordance with the classification provided by Pais et al. (2008), in which, (a) RCAj>1 means the country has revealed a comparative advantage for soybean exports; and (b) RCAj<1 means the country has revealed comparative disadvantage for soybean exports.

According to Table 6, the values found for the RCA of the Brazilian soybean are higher than the unit in the studied period. This indicates that the Brazilian soybean crop is a dynamic sector with great importance to the Brazilian export agenda.

The calculated RCA values from 2004 to 2014 were higher than the unit, indicating that Brazil has comparative advantage or competitiveness in the exports of this commodity. The RCA presented increasing values over the studied period, confirming the competitiveness of the Brazilian product.

The RCA analysis indicates that the soybean complex is a dynamic and competitive sector of the Brazilian economy, being this oleaginous plant one of the products responsible for the growth of Brazilian agribusiness. It was verified that there was growth of soybean production to meet international demand.

DISCUSSION

Brum et al. (2005) state that soy was one of the main factor responsible for the introduction of the concept of agribusiness in the country, not only for the physical and financial volume, but also for the need of activity management by the producers, suppliers of inputs, premiums and dealers. Casarotto (2013) adds that the generation of technologies was one of the fundamental factors for Brazil to increase its soybean production, becoming the first among the largest soybean producers in the world.

Brum et al. (2005) argue that the United States has advantages in the production and commercialization of soybeans compared to Brazil in terms of lower production and storage costs, in addition to greater investments in research and adequate infrastructure. Argentina has comparative advantages compared to Brazil due to lower transport costs, lower tax burden and ease of production flow. According to these authors, Brazil has advantages over the United States and Argentina regarding the availability of area for significant increases in production.

The United States has great productive and export capacity due to the wide power it has in the international market. This presence rests on tripod infrastructure, the efficiency with large-scale productivity, and official subsidies. The infrastructure comes in several aspects: high-performance equipment and implements, facilities for fleet renewal, specific strategies for the vast regions of a hostile climate. In addition, it has efficiency in its processes and transportation logistics. In the case of logistics, this country uses rail and water transport, with integration between modes; a model to be followed by other exporting countries (Ripoll, 2012).

From the analysis the three main exporting countries, there are differences regarding the logistics issue of the commodity in each of them. When analyzing the transport matrixes of soybeans in Argentina and the United States, it can be observed that in the former, although 80% of the soybean flow is carried out by road transport, average distances between producing regions and ports are close to 300 km, thus reducing cost of transportation. In the United States, which has high distances between producing regions and ports, the average distance ranges between 1,000 and 2,000 km, from which about 60% of the matrix is formed by waterways. According to Ripoll (2012), the transportation cost of the waterway model is 61% lower than road and 37% lower than rail. Thus, the transportation costs of grain in the United States are lower compared to Brazil.

Brazil has bottlenecks in their ports, which affect the competitiveness of Brazilian soybeans. The most detrimental port factors to the competitiveness of Brazilian exports are: high cost of port tariffs; higher demand than the installed capacity of terminals and warehouses; lack of investments in the expansion of port facilities, causing queues of trucks and ships during the harvest period; and the limitation of depth, preventing the mooring of larger ships in some ports. Another factor that raises costs in Brazil is that road transport is the main modal, which ends up affecting the prices received by producers negatively (IEAG, 2015).

The expansion of the product's participation in the foreign market requires guidance aimed at overcoming bottlenecks in infrastructure and logistics that affects the national agricultural sector. Another issue is to seek mechanisms that can help reduce the influence of international prices, since the prices of the Brazilian product oscillate according to the demand and supply of the product in the international market currently. Despite being a characteristic that governs the trade of primary products and commodities, this factor imposes some obstacles to the growth of export revenue.

In addition to the importance of technology, the adaptation of soybeans to the regions of the country encouraged the increase of cultivated areas. Another factor was the growing demand from domestic and foreign markets. Data from the Brazilian Association of Vegetable Oil Industries (ABIOVE, 2016) indicates that the soy complex is responsible for approximately 1.5 million jobs in 17 Brazilian states.

According to Brum (2005), for Brazil to expand its participation in the world soybean market, it must face some challenges, such as greater integration among the agents of the production chain, investment in biotechnology, availability of credits and a reinforcement aimed at actions of crops sanity. In addition, several factors can contribute to the expansion of production and exports, especially the fact that it has large unexplored or insufficiently exploited areas that could be incorporated into production and potential for the technological evolution in research companies.

It is important to point out that Brazil is facing a situation where the boundaries for the expansion of agricultural productions are given by logistics, and not by the availability of land suitable for agricultural production (Martins et al., 2005). However, as Colonel et al. (2009) argue, to continue as an important exporter, Brazil needs to overcome several internal obstacles such as reduction of transportation and logistics costs, better infrastructure conditions and greater investments in research. It also needs to seek alternatives to the World Trade Organization (WTO) to reduce the tariff and non-tariff barriers that the main importers imposed on soybean agribusiness.

The results of the current study explores the knowledge of international soybean market, identify the main internal and external obstacles that must be overcome, the factors that contributes the most to the soybean agribusiness exports, and the markets to which the soybean is exported. In this way, the study contributes suggestions related to the implementation of trade policies and the redirection of soybean products in the markets that show greater dynamism in their imports.

Conclusion

In the last years, the international market has been affected by an increasing demand due to the growth of exports and imports. This market has great economic importance for Brazil; it presents them opportunities like prominence in their exports for products such as soybean. Therefore, the current study sought to know the participation in the world market and evolution of soybean exports from the main exporters: the United States, Brazil and Argentina.

In relation to the United States, it proved to be the largest producer and exporter in the study period. Its position is due to the power it exerts in the international market because of the quality of its infrastructure, equipment of high performance, efficiency and transportation logistics.

Argentina presented potential for growth in its production and exports as it has the capacity for territorial expansion. However, it is necessary that economic and technological incentives take place. It ranks third among the world's largest producers and exporters.

Brazil stood out in the world market, occupying the second place among the biggest producers and exporters during the analyzed period. Its potential has been proven by the evolution of its share in the world's soybean exports, with significant and constant growth rates. It has the capacity to remain at the top positions in the ranking of the largest exporters in the world. This fact has positive consequences, with social and economic contributions, to the development of the country.

It is concluded that the Brazilian soybean exports are competitive in the international market based on the indicators of competitiveness, Constant Market Share and RCA. The results show that the destination of the exports and competitiveness represent a significant position in the world market, since it indicates that Brazil exports to countries that present dynamic forces in the foreign market, and has competitiveness in the world soybean market and standard efficiency and uses resources like those of the world force.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

ABIOVE (2016). ABIOVE - Associação brasileira das indústrias de óleos vegetais. Importância econômica e social.http://www.abiove.org.br/site/index.php?page=importancia-economica-e-social&area= NC0yLTI=. Accessed 10 January 2016.

Almeida AN (2010). Comparação entre a competitividade do Brasil e Canadá para a produção de madeira serrada.

Angelo H (1998). As exportações brasileiras de mogno (Swietenia macrophylla, King). Revista Árvore, 22(1), 113-121.

Balassa B (1965). Trade liberalisation and "revealed" comparative advantage 1. The manchester school 33(2):99-123.

Brum AL, Heck CR, Lemes CL, Müller PKA (2005). A economia mundial dasoja: impactos na cadeia produtiva da oleaginosa no Rio Grande do Sul 1970-2000. Anais dos Congressos. In XLIII Congresso da Sober em Ribeirão Preto. São Paulo.

Caro D, Davis SJ, Kebreab E, Mitloehner F (2018). Land-use change emissions from soybean feed embodied in Brazilian pork and poultry meat. Journal of Cleaner Production 172:2646-2654.

Carvalho FD (1995). O comportamento das exportações brasileiras e a dinâmica do complexo agroindustrial. Piracicaba: ESALQ.

Carvalho KD, Costa CDM, Soares NS, Silva ML (2010). Desempenho das exportações brasileiras de papel. Scientia Forestalis 38(86):263-271.

Casarotto EL (2013). Desempenho da pauta de exportações do agronegócio de Mato Grosso do Sul. Dourados: UFGD.

Coelho MRF, Berger R (2004). Competitividade das exportações brasileiras de móveis no mercado internacional: uma análise segundo a visão desempenho. Revista da FAE 7(1).

CONAB - Companhia Nacional de Abastecimento (2015). Séries históricas. https://www.conab.gov.br/info-agro/safras/serie-historica-das-safras. Accessed January 2017.

Coronel DA, Machado JAD, Carvalho FMA (2008).. Fontes de crescimento e orientação regional das exportações brasileiras do complexo soja.

Coronel DA, Machado JAD, Carvalho FMA (2009). Análise da competitividade das exportações do complexo soja brasileiro de 1995 a 2006: uma abordagem de market-share. Revista de economia contemporânea. Rio de Janeiro. Vol. 13, n. 2 (maio/ago. 2009), p.[281]-307.

Fajnzylber O, Sarti F, Leal JPG (1993). Estudo da competitividade da indústria brasileira: sistema de indicadores da competitividade. Campinas: UNICAMP.

FAO - Food and Agriculture Organization (2015). Statistical databases. Disponível em http://www.fao.org/home/en/. Accessed November 2017.

FAO - Food and Agriculture Organization (2015). Bridging the gap-FAO´s programme for gender equality in agriculture and rural development. http://www.fao.org/docrep/012/i1243e/i1243e00.htm . Accessed 20 November 2017.

Ferraz JC, Kupfer D, Haguenauer L (1995). Made in Brazil: desafios competitivos para a indústria. Rio de janeiro: Campus 386 p.

Figueiredo AM, Santos ML, Lírio VS (2004). Análise de market-share e fontes de variação das exportações brasileiras de soja. Revista de Economia e Agronegócio 2(3).

Fries CD, Coronel DA, Vieira KM, Bender Filho R (2013). Análise do crescimento das exportações do agronegócio gaúcho: uma aplicação do método constant-market-share. Revista Eletrônica em Gestão, Educação e Tecnologia Ambiental 17(17):3388-3400

Grams JC, Cypriano LA, Coronel DA, Martins RS (2013). Competitividade das Exportações da Indústria Automobilística Brasileira. Uma Análise Constant-Market-Share. Desenvolvimento em Questão 11(23).

Horta MH (1983). Fontes de crescimento das exportações brasileiras na década de 70.

Instituto Brasileiro de Geografico e Estatística (IBGE) (2016). Estatística da produção agrícola janeiro de. ftp://ftp.ibge.gov.br/Producao_Agricola/Levantamento_Sistematico_da_Producao_Agricola_[mensal]/Fasciculo_Indicadores_IBGE/2016/estProdAgr_201601.pdf . Accessed June 2017.

Instituto De Estudos Do Agronegócio (IEAG) (2015). O futuro da soja nacional. ABAG, 2015. 28p. http://www.abag.com.br/conteudos/interna/abag-ieag

Leamer EE, Stern RM (1970). Quantitative International Economics, Allyn and Bacon Inc.

Machado LVN, Amin MM, Carvalho FMA, Santana AC (2006). Análise do desempenho das exportações brasileiras de carne bovina: uma aplicação do método constant-market-share, 1995-2003. Revista de Economia e Agronegócio 4(2).

Maia SF, Rodrigues MB, Silva CC (2005). Avaliação do proex para obtenção da vantagem comparativa brasileira do setor agrícola brasileiro de 1989-2003. Revista Economia e Desenvolvimento 4(1).

Ministério da Agricultura, Pecuária e Abastecimento (MAPA) (2016). Disponível em: http://www.agricultura.gov.br/assuntos/politica-agricola. Accessed June 2017.

Martins RS, Lemos MB, Cypriano LA (2005). Impactos da carência de investimentos na logística pública de transportes para o agronegócio: discussão teórica e evidências para o caso brasileiro. In Congresso Da Sober (Vol. 43).

Noce R, Silva ML, Souza AL, Silva OM, Mendes LM, Carvalho RC, Valverde SR (2008). Competitividade do Brasil no mercado internacional de aglomerado. Revista Árvore 32(1).

rganização das Nações Unidas para Alimentação e Agricultura/ Food and Agriculture Organization (OECD-FAO) (2015). Perspectivas agrícolas 2015-2024. Revista FAO. OECD/FAO. Jul/2015. http://www.fao.org/3/a-i4738s.pdf

Oliveira AC (2014). Competitividade e parcela de mercado: uma abordagem constantmarketshare para a soja em grão brasileira (2000-2011). 2014. 54f. Trabalho de conclusão de curso (Ciências Econômicas). Universidade Federal de Alfenas, Varginha. https://www.unifal-mg.edu.br/economia/sites/default/files/economia/4_monografias/2014_2_Monografia%20Anast%C3%A1cia%20Cristina%20de%20Oliveira.pdf

Oliveira PB (2005). Competitividade e saldos comerciais da indústria agroalimentar no Brasil (Doctoral dissertation, Dissertação de Mestrado. Universidade Federal de Uberlândia, Uberlândia. 167 p).

Pais PS, Gomes MFM, Coronel DA (2011). Análise da Competitividade das Exportações Brasileiras de Minério de Ferro, 2000 A 2008. Revista de Administração Mackenzie (Mackenzie Management Review) 13(4).

Parapinski ML (2012). Desempenho das exportações brasileiras de móveis de madeira, 1991 a 2010 [dissertação]. Curitiba: Programa de Pós-Graduação em Engenharia Florestal, Universidade Federal do Paraná.

Raucci GS, Moreira CS, Alves PA, Mello FF, de Almeida Frazão L, Cerri CEP, Cerri CC (2015). Greenhouse gas assessment of Brazilian soybean production: a case study of Mato Grosso State. Journal of Cleaner Production 96:418-425.

Richardson JD (1971). Some sensitivity tests for a" constant-market-shares" analysis of export growth. The Review of Economics and Statistics pp. 300-304.

Ripoll FG (2012). Proposta de uma análise logística no agronegócio como fator competitivo para a distribuição e comercialização da soja em grão no Estado de Mato Grosso.

Ropke CRV, Palmeira EM (2006). Competitividade das exportações brasileiras de couro. Revista académica de economia 71:1-7.

Sanches AC, Michellon E, Roessing AC (2004). Os limites de expansão da soja. Informe GEPEC 9(1).

SECEX Secretaria de Comércio Exterior (2013). Comércio Exterior. http://www.mdic.gov.br/comercio-exterior/estatisticas-de-comercio-exterior/. Accessed July 2017.

Silva AC, Lima EPC, Batista HRA (2011). A importância da soja para o agronegócio brasileiro: uma análise sob o enfoque da produção, emprego e exportação. V Encontro de Economia Catarinense.

UN COMTRADE - United Nations Commodity Trade Statistics Database (2015). https://comtrade.un.org/. Accessed jun/ 2015.

United States Department of Agriculture (USDA) (2015). http://www.usdabrazil.org.br/pt-br/reports/oilseeds-and-products-annual.pdf. Accessed July 2017.

Valverde SR, Soares NS, Silva ML (2006). Desempenho das exportações brasileiras de celulose. Revista Árvore 30(6):1017-1023.

Vol. 13(44), pp. 2510-2515, 1 November, 2018
DOI: 10.5897/AJAR2015.10243
Article Number: C50D1D059103
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Factors affecting adoption of sustainable soil management practices among vegetable producers in Dhading, Nepal

Ghimire Binod[1*], Dhakal Shiva Chandra[2], Sharma Sujeeta[2] and Poudel Sujit[2]

[1]Department of Agriculture, Ministry of Agriculture and Livestock Development (MoALD), Nepal, India.
[2]Department of Agricultural Economics and Agribusiness Management, Agriculture and Forestry University, Chitwan, Nepal, India.

Received 4 August, 2015; Accepted 15 October, 2015

A research was conducted using primary data for the year 2012 obtained from randomly selected 120 vegetable farmers using pre-tested semi-structured interview schedule. Nalang and Salang VDCs of Dhading district in Nepal were purposively selected for the study. Different variables were fed to probit regression model to identify and quantify the major factors affecting the adoption of sustainable soil management technology. Overall, the model predicted 85.76%of the sample correctly. The findings of the study revealed that number of economically active family members, household head education, livestock holding, membership in farmer's group and credit availability affects positively whereas, age of household head affects negatively in the adoption of sustainable soil management technology. A unit increased in economically active family members, years of education and livestock standard unit would increase the probability of adoption of technology by 21.3, 5.8 and 7.6% respectively. Likewise, if farmers were made member in the groups and credit made available, the probability of adoption of technology would increase by 46.2 and 46.3% respectively. But a unit increased in the age of household head would decrease the level of adoption by 1.4% indicating old aged farmers do not adopt innovative technologies in agriculture.

Key words: Nepal, adoption, probit, sustainable soil management, vegetable.

INTRODUCTION

Dhading district of Nepal is one of the highly vegetable producing districts of Nepal which produces 74797 metric tons under total area of 6051 ha with the yield of 12361 kg/ha in year 2011/2012 (MoAD, 2012). Among commercial vegetable growers in Dhading district extremely hazardous pesticides are being used in vegetables which were banned for normal agriculture use by Government of Nepal (Shrestha et al., 2010). With the initiation of commercial vegetable cultivation, there is increasing trend of chemicals use. Excessive application of chemical fertilizers and pesticides is causing the partial desertification in many pocket areas of agriculture. Also, huge amount of money is being spent for the import of chemical fertilizers and pesticides every year.

*Corresponding author. E-mail: binodghim@gmail.com.

Total sale of chemical fertilizers in Nepal is 144813.48 mt. in 2011/2012 composed of 97956.51 mt. of urea, 43146.06 mt.of DAP and 3710.91 mt. of Potash (MoAD, 2012). The small farmers cannot afford these chemical fertilizers because the soil needs more and more of these chemical (Subedi et al., 2001).

On the other hand, excessive use of chemicals in agriculture is reducing soil fertility. Almost 98% of the soil in Nepal is deficient in organic matter (Tripathi, 2002). Poor soil fertility status of the farmland in the middle Hills of Nepal is a major constraint faced by the farmers (Pandey, 1995). Thus, the concern of feeding a fertile population from infertile soil in fragile and marginal agricultural land in mid-hills of Nepal is really a dilemma. To cope with the situation of pesticide hazards and environment deterioration, sustainable soil management practices are providing a suitable alternative which was brought in practice in commercial vegetable production under SSMP program. Sustainable soil management (SSM) practices are compatible with the capabilities of rural communities and smallholder farmers who generally lack capital to buy synthetic pesticides and inorganic fertilizers. In some situations SSM based growers may be less vulnerable to natural and economic risks than conventional farmers since their systems are usually more diversified (Olson et al., 1982). Also, addition to this Nowadays, various areas in the world have faced water logging and salinity problems, which are intensified by a myriad of factors including use of wastewaters for irrigation, unsuitable cropping pattern, torrential rains and floods, lack of sufficient drainage, uncontrolled drainage, lack of adequate knowledge, wrong management decisions, very poor construction and rehabilitation rates of drainage systems, increase of irrigation systems without paying any attention to their adverse impacts on soil and quality of water resources, etc. (Valipour, 2014).

Although, there are many agricultural technologies nowadays available for farmers which are eco-friendly and sustainable, their use and sustainable adoption is lacking. Farmers are adopting such practices whose profitability, sustainability, and viability are not known to them. Though here is availability of resource conserving and sustainable technologies for cultivation, poor extension and adoption is one of the problems in Nepalese agriculture development. Thus finding out the level of adoption and the major factors influencing adoption of such eco-friendly SSM practice is an urgent need. The specific objectives of this research work were:

(i) To find the level of adoption of SSM practice among the vegetable farmers.
(ii) To identify the major factors influencing the level of adoption of SSM practice.
(iii) To quantify the factors influencing in adoption of SSM practice.
(iv) To recommend best suggestions for increasing the level of SSM practice.

MATERIALS AND METHODS

Primary data was collected using semi-structured interview schedule in June, 2012. One hundred and twenty vegetable producers were randomly selected from Nalang and Salang VDCs of Dhading district for the study. Adoption index was used to calculate the level of SSM practice adoption. Different scores were assigned to the responses made by the respondent using checklist. Selected individuals were categorized in to different categories of adopters' level as high adoption, medium adoption, and low adoption. On this basis of adoption level, index was determined as adoption of SSM innovation. The level of technology adoption was calculated by using the following formula (Dongol, 2004).

$$Adoptionindex(AI) = \frac{Total\ score\ obtained\ by\ an\ individual}{Maximum\ possible\ score} \times 100$$

For determining factors affecting level of adoption of SSM practices, probit regression model was applied in this study. In many studies investigating the factor influencing the adoption of agricultural practices use has been made of probit models (Hattam, 2006). The characteristic feature of probit models is that the effect of independent variables on dependent variables is non-linear. It is a statistics model which aims to form a relation between probability values and explanatory variables and to ensure that the probability value remains between 0 and 1.

In the Probit model, suppose Y_i be the binary response of the farmers and take only two possible values; Y = 1, if farmer's adoption level is more than 84% and Y = 0, if less than 84% (Bhusal, 2012). Suppose x be the vector of several explanatory variables affecting to the level of adoption and β, a vector of slope parameters, which measures the changes in x on the probability of the farmers to adopt the practice at higher level. The probability of binary response was defined as follows:

If $Yi = 1$; $Pr(Y_i = 1) = P_i$
$Y_i = 0$; $Pr(Y_i = 0) = 1-P_i$

Where, $P_i = E(Y = 1/x)$ represents the conditional mean of Y given certain values of X.

According to Nagler (2002) probit model constrains the estimated probabilities to be between 0 and 1 and relaxes the constraint that the effect of the independent variables is constant across different predicted values of the dependent variables. This is normally experienced with the Linear Probability Model (LPM). The advantage of probit model is that it includes believable error term distribution as well as realistic probabilities. There were several factors that affect to the level of adoption of the practices at the farm level. Decision to adopt at higher level might be influenced by several socioeconomic, demographic, institutional and financial conditions. The aim of the model is to predict the influence of variables (X) on the probability of adoption of sustainable soil management practices (Y, dependent variables). According to this, in the probit model the likelihood of farmers adopting SSM practices is a non-linear function of variables.

$Pr(Y=1) = (X\beta)$

Model specification

The Probit model specified in this study to analyze factors affecting farmer's level of adoption of sustainable soil management practices was expressed as follows (Table 1):

$$Pr(>84\%=1) = f(b_0+ b_1 X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} +b_{11}X_{11})$$

Table 1. Description of the variables used in the Probit model.

Variable	Type	Description	Value	Expected sign
Dependent variable Yi	Dummy	Farmers scoring more than 84% in adoption score.	1 if farmer secured score> 84%; 0 otherwise	
Independent variables economically active members	Continuous	Number of economically active (16-59years) family members in the household	Number	+
Education	Continuous	Years of education of the household head	years	+
Farm size	Continuous	Total size of cultivated land	Ropani*	+
Experience	Continuous	Experience of household head in vegetable farming	Year	+
Gender	Dummy	Gender of the household head	1 if male; 0 otherwise	+/-
Age	Continuous	Age of the household head	years	+
Training	Dummy	Whether farmers received training from different governmental and non-governmental organization.	1 if farmers received training ; 0 otherwise	+
Livestock holding	Continuous	Livestock holding	Livestock Standard Unit, LSU	+
Membership	Dummy	Participation of respondent on SSM farmers group	1 if yes; 0 otherwise	+
Credit	Dummy	Whether farmer had access of credit	1 if farmers had access to credit; 0 otherwise	+

*1 ha = 19.66 ropani

Where,
Pr (> 84%) = Probability score of adopting SSM practices
$b_1, b_2 \dots b_{11}$= Probit coefficient
b_0= Regression coefficient

RESULTS AND DISCUSSION

Socio-demographic characteristics of respondent in the study area

Total population of sampled households in the study area was 726 of which male population was 53.45% with average family size 6.15. Average age of household head was 56.6 years. Among total population 51% were economically active of which 82.5% of household were male headed and 65% of the household were found with nuclear family. About 63% were found literate total area owned in an average was 13.42 ropani of which 11.95 ropani was cultivated and only 3.18 ropani was under irrigation. Among the total respondent about 62% had received trainings related to sustainable soil management based vegetable farming and 65.8% were participated in farmers group. The average livestock holding was 10.12 LSU in the study area.

Level of technology adoption

Majority of the respondent that is, 46.67% had medium level of adoption (77-91% level) of sustainable soil management practices. From the study 25.83% respondent was at high level whereas, 27.50% were at low level. The mean level of adoption of the practice was 84.05 with mean standard deviation of 7.42 (Table 2).

Factors affecting the level of SSM technology adoption

The adoption level of the farmers in the study area was categorized into binary response by the adoption level of more than 84%= 1 and 0 otherwise. The extent to which the probit regression analysis model's independent variables used in prediction correctly predicted the dependent variable. Overall, the model predicted 85.76 per cent of the sample correctly. Thus the models developed may be said to be consistent and meaningful. The wald test (LR chi^2) for the model indicated that, the model had good explanatory power at the 1% level. The Pseudo R^2 was 0.777. For the interpretation of the model, marginal effects were driven from the regression coefficients, calculated from partial derivatives as a marginal probability. The interpretation is shown in Table 3. Probit regression analysis showed six variables were statistically significant for the level of adoption and they were; economically active family members, education, age, livestock standard unit, membership and credit. Five other variables namely experience, occupation, training and gender were statistically non-significant and associated positively with adoption while farm size was negatively associated (Table 3).

The study revealed that, number of economically active family members was positively significant ($P<0.05$) and keeping other factors constant, a unit increase in the number of economically active family members, probability of level of adoption would increase by 21.3%. This might be due to the availability of the more labor force in the agricultural activities. Similar to this, Teklewold et al. (2006) reported that the higher size of the household reduces the labor constraints and influence

Table 2. Level of adoption of sustainable soil management practices by the farmers in the study area.

Level of adoption	VDCs		Total
	Nalang	Salang	
<77% (low)	16(26.67)	17(28.33)	33(27.50)
77%-91% (medium)	29(48.33)	27(45.00)	56(46.67)
>91%(high)	15(25.00)	16 (26.67)	31(25.83)
Total	60 (100)	60 (100)	120 (100)

Figures in parentheses indicate percentage, mean level of adoption=84.05%
Source: Field survey, 2012.

Table 3. Factors affecting the level of adoption of sustainable soil management practices in the study area.

Variable	Coefficients	P>|z|	Standard error	dy/dx[b]	S.E[b]
Economically active members(No.)	0.950**	0.014	0.385	0.213	0.094
Education (Years)	0.257***	0.008	0.097	0.058	0.029
Farm size (Ropani)	-0.003	0.935	0.042	-0.001	0.009
Experience (Years)	0.121	0.577	0.217	0.027	0.051
Gender (Dummy)	0.147	0.692	0.692	0.033	0.158
Age of HH (Years)	-0.653**	0.027	0.029	-0.014	0.006
Training (Dummy)	1.013	0.088	0.594	0.272	0.196
Livestock holding (LSU)	0.340**	0.034	0.164	0.076	0.024
Membership (Dummy)	1.918***	0.002	0.624	0.462	0.164
Credit availability (Dummy)	1.637**	0.011	0.644	0.463	0.207
Occupation (Dummy)	0.078	0.914	0.724	0.018	0.172
Constant	-6.121	0.008	2.318	-	-
Summary statistics					
Number of observation(N)			120		
Log likelihood			-18.248		
LR chi^2(10)		127.15***	(Prob>chi^2 = 0.000)		
Prob>chi^2			0.000		
Pseudo R^2			0.777		
Cases predicted correctly (%)			85.76		
Goodness of fit test		Pearson chi^2 (107) = 76.85. Prob> chi^2 = 0.9877			

*** Significant at P = 0.01; ** significant at P = 0.05.
Source: Field survey, 2012
[b]Marginal change in probability (marginal effects after Probit) evaluated at the sample means.

the adoption of new technology positively.

Higher education level of household head gives the ability to interpret and respond to new information much faster than their counterparts with lower education (Feder et al., 1985). The coefficient of level of education entered the model with a positive sign and highly significant (P<0.01). One year increase in education of household head would increase the level of adoption by 5.8%. This finding is in harmony with the report of Kattel (2009).

The age factor was negatively significant (P<0.05) and a unit increase in the age would decrease the adoption level by 1.4 percent. Ghimire and Kafle, 2014 resulted that age factor negatively affected the adoption of integrated pest management practices in Nepal. Also, finding is in line with (Mussei et al., 2001) but is in contrast with (Chebil et al., 2007). Hussain et al. (2011) also reported that elder farmers do not adopt the innovative technologies like IPM. Livestock holding was positively significant (P<0.05) and a unit increase in the livestock standard unit would increase the adoption level of SSM practices by 7.6%. Similar finding was also reported by Kudi et al. (2011) but the result contrast with (Dhital, 2010). Coefficient of membership was positive and highly significant (P<0.01 and if farmers were participated in a group related with sustainable soil management practices would increases the probability of adoption level by 46.2%. This might be due to the facts that, farmers gain high skills and knowledge while involving in groups and are in the direct influence of such practices. Similar result was reported by Nchinda et al. (2010). Study revealed that if farmers were provided credit facility, probability of adoption of SSM practice would increase by 46.3% which was positively significant ($P<0.05$). Tizale (2007) also indicated that there is a positive relationship between the intensity of use of various technologies and the availability of credit.

CONCLUSION AND RECOMMENDATIONS

The study concluded that for the adoption of any agricultural technologies there lies number of factors which affect the adoption process significantly. Though the introduction of SSM practices has a direct role in improving the income and nutrition of many mid-hill households in terms of both quantity and quality, many factors hinders the adoption of such useful practices. Result suggested that SSM practices could be well extended only after addressing the different socio-economic problems of the farmers. Economically active family members, education of household head, age of household head, livestock standard unit, membership and availability of credit to farmers were found as most significant factors affecting adoption of SSM practice in the study area. The conclusions that were drawn from above results in this study can be used to suggest some recommendation for the successful adoption of SSM technology at farm level. Some recommendations have been suggested below to heighten the adoption of SSM technology.

(i) Result of this study concluded that economically active members and availability of credit affects adoption of SSM technology. Hence, technologies along with incentives, trainings and credit should be provided to youth populace avoiding muscle and brain drain.
(ii) Adoption of SSM technology is significantly increased with increase in years of education of household head. Thus, Government should take action to upgrade education and also should provide knowledge through trainings, visit, demonstrations, seminars and workshop etc. for farmers as SSM practices are complex to understand, prepare and use from the farmer's level.
(iii) Study of this result showed the scope for higher income by adding livestock enterprise which also in the other hand increases the adoption of SSM technology.
(iv) The study exposed that older farmers do not adopt innovative technologies like SSM. Hence it is suggested that government should implement youth based program in SSM based vegetable production.
(v) The adoption of SSM technology speeds up if farmers were involved in groups. Membership in farmer groups exposes farmers to a wide range of ideas which may positively change their attitude towards an innovation such that for effective adoption, agricultural technologies should be handed through group approach.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

Our heartfelt thank goes to Institute of Agriculture and Animal Science (IAAS), Tribhuvan University, Nepal. Sincere gratitude to SSMP-HELVETAS, Swiss Inter cooperation Nepal, for providing fund to conduct this research work. Also we are grateful to the respondents of the study area for their cooperation, time and valuable information for the entire research period.

REFERENCES

Bhusal DR (2012). Impact of cattle urine use technology in farm income of the vegetable growers of Dhading district, Nepal. M.Sc. Agriculture Economics Thesis. Institute of Agriculture and Animal Science (IAAS). Rampur, Chitwan Nepal.

Chebil A, Nasr H, Zaibet L (2007). Farmer's willingness to adopt salt-tolerant forage in south-eastern of Tunisia In: Adding value to the Agro-Food Supply Chain in the Future Euromediterranean Space. Mediterranean Conference of Agro-Food Social Scientists.

Dhital PR (2010). Factors affecting adoption of recommended technology of cauliflower production in Kavre district of Nepal. M.Sc. Agriculture Extension and Rural Sociology Thesis. Institute of Agriculture and Animal Science (IAAS). Rampur, Chitwan Nepal.

Dongol BBS (2004). Extension Education.1st Ed. Dongol Printers 283 p.

Feder G, Just RE, Zilberman D (1985). Adoption of agricultural innovations in developing countries: A survey. Economic Development and Cultural Change 33(2):255-298.

Ghimire B, Kafle N (2014). Integrated pest management practices and its adoption determinants among apple farmers in Mustang, Nepal. Scholars Journal of Agriculture and Veterinary Sciences 1(2):83-89.

Hattam C (2006). Adopting organic agriculture: An investigation using the theory of planned behaviour. Poster paper prepared for presentation, International Association of Agriculture Economics Conference, Gold Coast, Austrailia.

Hussain M, Zia S, Saboor A (2011). The adoption of integrated pest management (IPM) technologies by cotton growers in the Punjab. Soil and Environment 30(1):74-77.

Kattel RR (2009). The impact of coffee production on Nepali smallholders in the value chain. Institute of Environmental Economics and World Trade, Leibniz Universitate. Hannover, Germany.

Kudi TM, Bolaji M, Ankinola MO, Nasa IDH (2011). Analysis of adoption of improved maize varieties among farmers in Kwara State, Nigeria. International Journal of Peace and Development Studies 1(3):8-12.

Ministry of Agriculture and Development (MoAD) (2012). Statistical information on Nepalese agriculture. Ministry of Agriculture and Development. Agri-Business Promotion and Statistics Division (ABPSD), Kathmandu, Nepal.

Mussei A, Mwanga J, Verkujil H, Mongi R, Elanga A (2001). Adoption of improved wheat technologies by small scale farmers in Mbeya District, Southern Highlands, Tanzania. Mexico, D. F.: International Maize and Wheat Improvement Centre (CIMMYT) and the United Republic of Tanzania.

Nagler J (2002). Interpreting probit analysis. New York University. Available at http://www.nyu.edu/classes/nagler/quant2/notes/probit1.pdf.(Accessed on 20/01/2015).

Nchinda VP, Ambe TE, Holvoet N, Leke W, Che MA, Nkwate SP, Ngassam SB (2010). Factors influencing the adoption intensity of improved yam (Dioscorea spp.) seed technology in the western highlands and high guinea savannah zones of Cameroon. Journal of Applied Biological Sciences 36:2389-2402.
Olson KD, Langley J, Heady EO (1982). Widespread Adoption of Organic Farming Practices: Estimated Impacts on U.S. Journal of Soil and Water Conservation 37(1):41-45.
Pandey ND (1995). The impacts of the farmers' practices on soil fertility management: A case study in Dhading Besi area, Middle Mountain Region, Nepal. AIT Thesis No: AE-95-44. Asian Institute of Technology, Bangkok Thailand pp. 47-59.
Shrestha PP, Koirala P, Thakur AS (2010). Knowledge practice and use of pesticides among commercial vegetable growers of Dhading district, Nepal. Journal of Agriculture and Environment 11:20-25.
Subedi KD, Jaisi S, Subedi TB, Mandal S, Dhital BK (2001). Gothemal tatha compost mal bewasthapan talim pustika. Sustainable soil Management Programme. SSMP, Bakhundol, Lalitpur, Kathmandu, Nepal 92 p.
Teklewold H, Dadi L, Yami A, Dana N (2006). Determinants of adoption of poultry technology: a double hurdle approach. Livestock Research for Rural Development 18:3.
Tizale CY (2007). The dynamics of soil degradationand incentives for optimal management in the Central Highlands of Ethiopia. Ph.D. Thesis, Department of Agricultural Economics, Extension and Rural Development, Faculty of Natural and Agricultural Sciences, University of Pretoria.
Tripathi BP (2002). Review of acid soil and its management in Nepal. In: Proceedings of the Third National Conference on Science and Technology. Nepal Academy of Science and Technology. Lalitpur, Kathmandu, Nepal.
Valipour M (2014) Drainage, waterlogging, and salinity, Archives of Agronomy and Soil Science 60(12):1625-1640.

Vol. 13(44), pp. 2516-2525, 1 November, 2018
DOI: 10.5897/AJAR2018.113431
Article Number: AC6FA5259105
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Seed-priming of sorghum with antifungal extracts from *Balanites aegyptiaca* and *Eclipta alba* in different agro-ecological zones of Burkina Faso

P. E. Zida[1], B. J. Néya[1], R. W. Soalla[1], P. Sérémé[1] and O. S. Lund[2]

[1]Institut de l´Environnement et de Recherches Agricoles (INERA), P. O. Box 8645, Ouagadougou 04, Burkina Faso.
[2]Department of Plant and Environmental Sciences, University of Copenhagen, Højbakkegård Allé 13, 2630 Taastrup, Denmark.

Received 1 August, 2018; Accepted 16 October, 2018

Seed-priming of sorghum with an aqueous extract from the herbal plant, *Eclipta alba* has previously been found to increase crop yield of sorghum in Burkina Faso dependent on field location. In the present study, a 2.5% w/v antifungal extract from the desert tree, *Balanites aegyptiaca*, was similarly shown to increase the yield of sorghum by seed treatment. The effect was compared to the effect of *E. alba* extract on different types of seeds in different locations. A participatory trial including forty-six fields in three agro-ecological zones was conducted using local, farm-saved seeds. The overall effect on yield conferred by the *B. aegyptiaca* extract was significantly higher than the effect conferred by the *E. alba* extract (+31% versus +21%, *p*<0.03). However, in one zone the opposite hierarchy was observed; also when formally propagated, seeds were used for testing. The same, South-Eastern zone was characterized by poor crop performance despite a relatively high rainfall. Antifungal activity was confirmed in both extracts *in vitro* and different levels of protection against the pathogen *Curvularia lunata* were demonstrated in seedlings. The findings are encouraging for a regionally differential use of botanicals in seed treatment and more research to understand local differences in the crop response is suggested.

Key words: Bio-priming, *sorghum bicolor*, emergence, mycoflora, *Epicoccum*, *Fusarium*.

INTRODUCTION

In Burkina Faso, seeds of sorghum are commonly infested by pathogenic ascomycetes such as *Epicoccum sorghinum* (prev. *Phoma sorghina*), *Fusarium thapsinum* (prev. *F. moniliforme*) and several species of *Curvularia* (*Curvularia lunata*, *Curvularia alcornii* and others) (Prom et al., 2003; Zida et al., 2008a; Stokholm et al., 2016). Soaking of sorghum seeds for 6 h in 2.5% w/v aqueous extract of *Eclipta alba* reduced symptoms of fungal infection in seedlings and yield was increased by approximately 20% in a field trial involving multiple locations (Zida et al., 2015). Subsequently, it was recently found that the yield enhancing effect of *E. alba*

*Corresponding author. E-mail: osl@plen.ku.dk

extract is likely to be caused by a dual mechanism of seed hydropriming and suppression of fungal pathogens (Zida et al., 2018). The plant *E. alba* (L.) Hassk. (syn.: *Eclipta prostrata* Eng.: False daisy) is known as an annual weed in the family Asteraceae and is found globally in humid tropical and subtropical areas (Holm et al., 1977). Line drawings for its identification, photographs and distribution maps can be found online in CABI compendium of invasive species (CABI, 2018). *E. alba* has a strong record in ethno-botanical medicine and cosmetology (Bhalerao et al., 2013; Jahan et al., 2014; Begum et al., 2015). Several complex alkaloids have been identified in *E. alba* and antifungal activity is attributed to the compound 25-*β*-hydroxyverazine (Abdel-Kader et al., 1998).

In Burkina Faso, *E. alba* is commonly found in Central and Southern parts of the country, where humidity occurs at least periodically (Zida et al., 2008b). A country-wide field trial showed a moderate ability of *E. alba* extract to increase yield of sorghum (Zida et al., 2012). However, the effect of *E. alba* extract is highly dependent on the field location with a significant tendency of a stronger effect found on fields showing a low emergence of sorghum (Zida et al., 2016). Thus, a strategy of using *E. alba* extract for seed treatment in Burkina Faso faces two major challenges: (1) the plant is not commonly found in the northern parts of the country and (2) the effect is highly variable between locations. In order to mitigate these challenges, the objective of the present study was to test an alternative extract from the plant, *Balanites aegyptiaca*, found widely in Burkina Faso and for which antifungal activity is also known (Bonzi et al., 2012).

B. aegyptiaca Del. (family Zygophyllaceae; Eng.: Desert date) is a thorny tree distributed mainly in drylands of sub-Saharan Western Africa (Arbonnier, 2002). A distribution map and pictures for its identification can be found online (GBIF, 2018). Like *E. alba*, the *B. aegyptiaca* tree is a well-known medicinal plant, with a high number of complex compounds including saponins identified (Chothani and Vaghasiya, 2011). To our knowledge, none of them have yet been attributed directly to antifungal activity. In the present study, testing of the *B. aegyptiaca* aqueous bark extract in seed treatment included direct comparison to water (hydropriming) and to *E. alba* extract by testing on multiple locations across different agro-ecological zones. Both farm-saved and formally propagated seeds were used as testing material. The study area of field experiments included three different sorghum-growing regions: (A) Northern, (B) Central, and (C) South-Eastern Region (Figure 1). The Northern region (Zone A) is characterized by low rainfall (less than 600 mm annually) and dry-land agriculture including sorghum as the second most important crop next to pearl millet (INSD, 2016; De Longueville et al., 2016). The Central region (Zone B) consists of the capital, Ouagadougou, and has an annual rainfall between 600 and 900 mm. In the rural districts of zone B sorghum is the main crop (INSD, 2016). Zone C (the South-Eastern area) has an annual rainfall close to 900 mm. This zone contains the highest biodiversity of wild plant species in Burkina Faso (Schmidt et al., 2005) and sorghum is the main crop followed by maize (INSD, 2016).

Figure 1. The study area. Fourteen locations (villages) of field test sites distributed across three major agro-ecological zones of sorghum are shown. A) Northern Zone. B) Central Zone. C) South-Eastern Zone. Fifty-years isohyets of 600 mm and 900 mm are indicated by colors according to De Longueville et al. (2016). In the participatory field trial in 2017 involving 46 farmers all the fourteen locations shown were included with 2-4 farmers and fields included in each village.

Fourteen locations (villages) of field test sites distributed across three major agro-ecological zones of sorghum are shown: (A) Northern Zone; (B) Central Zone; (C) South-Eastern Zone. Fifty-years isohyets of 600 and 900 mm are indicated by colors according to De Longueville et al. (2016). In the participatory field trial in 2017 involving 46 farmers, all the fourteen locations shown were included with 2 to 4 farmers and fields included in each village.

In addition to field trials, several experiments were carried out *in vitro* to compare the two plant extracts with regard to antifungal effect and protection of sorghum seedlings from fungal seed inoculum.

MATERIALS AND METHODS

Seeds

In the field trial with 36 field tests comparing treatment with *B. aegyptiaca* extract and hydropriming, seeds of two varieties of sorghum were included: Kouria (13 field tests) and Kapelga (23 field tests). Both varieties were propagated by the Institute of Environment and Agricultural Research (IN.E.R.A, Burkina Faso). In the subset of 21 experiments including also treatment with *E. alba* extract only seeds of variety Kapelga were included. In the field trial with farm-saved seeds, forty-six seed samples from each of forty-six farmers from a total of 14 different villages were used (14

Table 1. *B. aegyptiaca* extract tested against hydropriming in seed treatment of sorghum (formal seeds).

Year	N	Yield parameter	Treatment			ANOVA
			NoT	H_2O	Ba2.5%	One-way
2015	9	Mean kg/ha	942	1231	1464	
2017	27	Mean kg/ha	837	941	937	
Total	36	Mean kg/ha	863	1014	1069	
		Field average (%)*	87.8	101.1	109.9	<0.00006
		Yield increase %	-	+15.1%	+25.2%	
		p(NoT)	-	<0.009	<0.00004	
		p(H_2O)	-	-	<0.04	

N = Number of field test, NoT = No Treatment, H_2O = Hydropriming, Ba= *B. aegyptiaca* extract. Field experiments were carried out on varieties Kouria and Kapelga in Northern, Central and South-Eastern parts of Burkina Faso.
*Yields in NoT-plots varied from 130-2800 kg/ha between fields. To avoid a bias from high-yielding fields, statistics were made only on field averaged values (%).

villages is as shown in Figure 1). Two to four farmers from each village were included. Each seed sample was tested only on the farmers own field. For experiments *in vitro*, seeds of the cultivar Kapelga (sample 49.071) propagated by IN.E.R.A and farm-saved seeds from the village Diapangou (sample 40.066) were used as indicated.

Plant extracts

Wild plants of *E. alba* were collected by uprooting (pulling by hand) of plants growing in humid sites in Central Burkina Faso. Soil particles on roots were removed by rinsing in tap water. Barks of *B. aegyptiaca* were collected from wild trees growing in fields near farmers' homes in several parts of Burkina Faso. Barks (soft parts) were removed from the trunk of the tree with the help of a pick. The material of both plants collected was air-dried, ground with a mortar into powder, and sieved with a mesh of approximately 2 mm diameter. Plant powders were stored in sealed plastic bags in darkness at room temperature until use. The preparation of aqueous extracts of *E. alba* and *B. aegyptiaca* followed the same procedure: the powder of both plants was mixed with distilled water at the concentration 2.5% (W/V) and incubated for passive extraction at 25 to 30°C for 20 h. Aqueous extracts were obtained by filtering the mixtures with pieces of cloth (hand filtering) and used the same day (no storing).

Seed treatments

Seeds used for field experiments were either not treated (NoT), soaked for 6 h in distilled water (H_2O) or in either of the two extracts. *E. alba* and *B. aegyptiaca* extracts were applied by soaking of seeds for 6 h in 2.5% extract of each plant. After treatment, seeds were dried at room temperature for one day before sowing. For seeds used in experiments *in vitro*, some were heat treated in a water bath at 55°C for 40 min as indicated (Hot Water, HW) in order to reduce the natural inoculum of seed borne fungi.

Field experiments

Experimental plots were prepared and managed as previously described (Zida et al., 2016). Shortly, for each treatment an experimental plot of at least 25 rows (80 cm spacing, 5 m length) was prepared per field in a random block design. Mineral fertilizer (NPK 14-23-14, 100 kg/ha) and urea (50 kg/ha) were applied. Sowing was done in May-June and harvesting was done in November-December according to local weather forecasts.

In the trial of 36 experiments testing *B. aegyptiaca* extract and hydropriming on formally propagated seeds (Table 1) experimental fields were distributed across all three zones (A, B and C; Figure 1). In the subset of 21 experiments including *E. alba* extract (Table 2) only fields in Zones B (11 fields) and C (10 fields) were included. In the participatory field trial including 46 farmers (Table 3) fields were located in 14 different villages distributed across three zones A, B and C as detailed in Figure 1. For each experimental plot, emergence was determined visually by counting the percentage of seed holes populated with emerging plants, 3 to 4 weeks after sowing. At harvest, grains were collected from each plot and yield was determined after 2 weeks of sun drying of the harvested grain. Data of annual precipitation were recorded at meteorological stations at Titao (Zone A), Ouagadougou (Zone B) and Diapangou (Zone C).

Fungal analysis

Mycoflora of seeds was enumerated by blotter test (Mathur and Kongsdal, 2003). Effect of seed treatments was assessed on the seed sample (variety Kapelga) used for field trials in 2017. Following seed treatments as described earlier (NoT, H_2O, *E. alba* 2.5% and *B. aegyptica* 2.5%) seeds were incubated for 7 days before enumeration of mycoflora. For each treatment, two replicas of the blotter test (each of 100 seeds) were conducted. For farm saved seed sample 49.066, 200 seeds were analyzed by blotter test and found to carry a natural inoculum (% seeds infected) of phytopathogenic fungi: *E. sorghinum* (53%); *Curvularia* species (28%), *Fusarium* species (13%).

Inoculation of seeds *in vitro*

Seeds of variety Kapelga (sample 49.071) were heat treated as described earlier (55°C hot water for 40 min) to eliminate natural fungal inoculum. After this treatment, seeds were divided in two groups: one group was inoculated with a spore suspension of *C. lunata* var. *aeria* (10^5 spores per ml, 15 min) and the second group was soaked in pure water as a control. Seeds were then air-dried and stored for at least 3 days before further treatment (H_2O, Ea2.5%, Ba2.5%) as described earlier or heat treated again (55°C, 40 min) as an anti-fungal control. The isolate of *C. lunata* was isolated from seeds of sorghum from Burkina Faso and identified by

Table 2. Hydropriming, *E. alba* and *B. aegyptiaca* extracts compared in two zones (Sorghum Yield, 2017).

Zone	N	Yield parameter	Treatment				ANOVA
			NoT	H_2O	Ea2.5%	Ba2.5%	One-way
B: Central	11	Mean kg/ha	844	966	889	930	Ns
		Field average (%)	94.9	105.9	97.8	101.4	
		Increase %	-	+11.6	+3.0	+6.9	
C: South-East.	10	Mean kg/ha	687	819	1013	730	<0.012
		Field average (%)	85.9	95.7	111.2	103.1	
		Increase %*	-	+11.3	+29.4	+20.0	
		p(NoT)*	-	Ns	<0.0092	<0.046	
		p(H_2O)*	-	-	<0.042	Ns	

N = Number of field tests, NoT = No Treatment, H_2O = Hydropriming, Ea= *E. alba*, Ba = *B. aegyptiaca*, ns = not significant. A total of 21 field test were performed on formally propagated seeds of sorghum variety Kapelga.
*Increase of yield (%) and statistics are based on field averaged values.

Table 3. Comparison of *E. alba* and *B. aegyptiaca* extracts on farm-saved seeds in three zones (Yield).

Zone	N	Yield parameter	Treatment			ANOVA
			NoT	Ea2.5	Ba2.5	One-way
A Northern	18	Mean kg/ha	529	629	742	<0.0004
		Field Av. %	83.2	98.6	118.1	
		% Incr.	-	+18.5%	+41.9%	
		p(NoT)	-	<0.03	<0.00009	
		p(Ea2.5)	-	-	<0.03	
B Central	15	Mean kg/ha	622	711	756	Ns
		Field Av. %	87.2	103.0	109.8	
		% Incr.	-	+18.1%	+25.9%	
C South-East.	13	Mean kg/ha	560	833	700	<0.009
		Field Av. %	85.6	109.3	105.1	
		% Incr.	-	+27.7%	+22.8%	
		p(NoT)	-	<0.009	<0.03	
		p(Ea2.5)	-	-	Ns	
Total	46	Mean kg/ha	568	713	735	<0.00002
		Field Av. %*	85.2^{a}	103.1^{b}	111.7^{c}	
		% Incr.	-	+21.0%	+31.1%	
		p(NoT)	-	<0.0003	<0.00005	
		p(Ea2.5)	-	-	<0.03	

N = Number of farmers, NoT = No Treatment, Ea = *Eclipta alba*, Ba = *Balanites aegyptiaca,* ns = not significant. *Figures in same row with same letters are not significantly different (Mann-Whitney paired test, p<0.05).

sequencing of *ITS2* region found identical to sequence KF218632 of isolate Curv-Bi-02 (Stokholm et al., 2016).

Analysis of seedlings *in vitro*

Seeds of sorghum (artificially inoculated, sample 49.071 or farm-saved seeds, sample 49.066 carrying a natural inoculum) were treated as described earlier (NoT; H_2O; *E. alba* 2.5%; *B. aegyptica* 2.5%; hot water treatment). After drying of seeds overnight, seedlings were grown from seeds in Hoagland medium as follows: the seeds were sown in 80 ml test-tubes (1 seed per tube) containing 20 ml solidified sterile Hoagland's plant growth medium no. 2. The plants were incubated in a climate chamber at 25°C/16°C day/night temperature and a light/dark ratio of 14/10 h using a continuous photon flux density of 58 to 65 µmol s^{-1} m^{-1} photosynthetically active radiation (PAR) for 16 days after sowing. At 16 days after sowing, dry weight of individual l shoots was

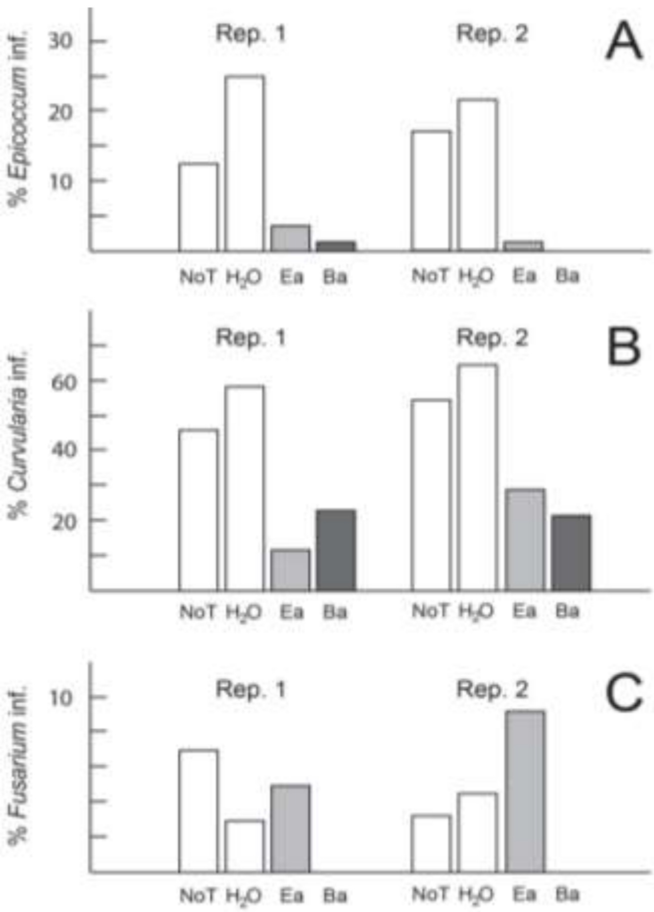

Figure 2. Effect of plant extracts on seed mycoflora. Two repetitions of blotter test showing % of seeds infected by genera (A) *Epicoccum*, (B) *Curvularia* and (C) *Fusarium*. Each replicate consist of 100 formally produced seeds (Kapelga).

measured. For farm-saved seeds (sample 49.066) carrying a natural fungal inoculum, root health was visually assessed by recording of presence/absence of black necrotic tissue. In the experiment with inoculation of *C. lunata* (Figure 3), two repetitions (2 × 24 seeds) were sown per treatment. In the experiment with farm-saved seeds (Figure 4), three repetitions (3 × 24 seeds) were sown per treatment. Before statistical analysis of experiments, 4 non-germinated or poorly germinated seeds/seedlings were removed for each treatment in each repetition.

Statistics

For each plot the yield was calculated in two ways: Absolute yield = kg/ha and relative yield (%) compared to the field average (the average yield of all plots of all treatments on the same field). Simple means of both types of yield were calculated. In order to eliminate field-to-field variation of the general yield level, one-way analysis of variance (ANOVA) was calculated for field averaged yields (%) using software PAST version 3.20 (Hammer et al., 2001). For all data sets with an overall significant ANOVA p-value (<0.05) pairwise comparison of each group was done by Mann-Whitney analysis (yield) or Wilcoxon analysis (emergence) using the aforementioned software. For comparison of individual treatments *in vitro*, data of shoot weight were analyzed by Mann-Whitney paired test and data for presence or absence of root necrosis were analyzed by Chi-square test (PAST version 3.20).

RESULTS

B. aegyptiaca extract compared to hydropriming

In two growing seasons, seed treatment with 2.5% *B. aegyptiaca* extract was compared to soaking of seeds in pure water (H_2O, hydropriming) and no treatment (NoT). Formally produced seeds were used as testing material in a total of thirty-six field experiments distributed across the Northern, Central and South-Eastern parts of the country. The total mean of yield (both absolute kg/ha and calculated as field average %) is shown in Table 1. For the field averaged values, one-way ANOVA was significant across all 36 experiments and the following hierarchy of yields was obtained: Ba2.5% > H_2O > NoT. Pairwise comparison of Ba2.5% relative to H_2O (field averaged values) showed a significantly stronger effect of the plant extract: p (H_2O)<0.04. In conclusion, seed treatment with the *B. aegyptica* extract was found to confer a specific increase of yield in Burkina Faso compared to controls of pure water and no treatment.
Field experiments were carried out on varieties Kouria and Kapelga in Northern, Central and South-Eastern parts of Burkina Faso.*Yields in NoT-plots varied from 130 to 2800 kg/ha between fields. To avoid a bias from high-yielding fields, statistics were made only on field averaged values (%).

Effect of *B. aegyptiaca* and *E. alba* extracts compared between two zones (formal seeds)

For the year 2017, a subset of the 27 field experiments described in Table 1 also included plots with seeds treated with *E. alba* extract. This subset of 21 experiments was re-analyzed by inclusion of data for *E. alba* and was stratified into zones B and C in order to reveal any zonal effect (Table 2).

A total of 21 field tests were performed on formally propagated seeds of sorghum variety Kapelga. Increase of yield (%) and statistics are based on field averaged values.

A significant difference between treatments was found by ANOVA only in the low-yielding, Zone C, with the observed hierarchy of treatments: Ea2.5% > Ba2.5% > H_2O> NoT. Both extracts were significantly more efficient than no treatment in Zone C, but only *E. alba* extract performed significantly better than hydropriming (p<0.042). Notably, the same effect of hydropriming was observed in the two zones (ca 11%) and in Zone B; this was the strongest effect observed for any of the treatments.

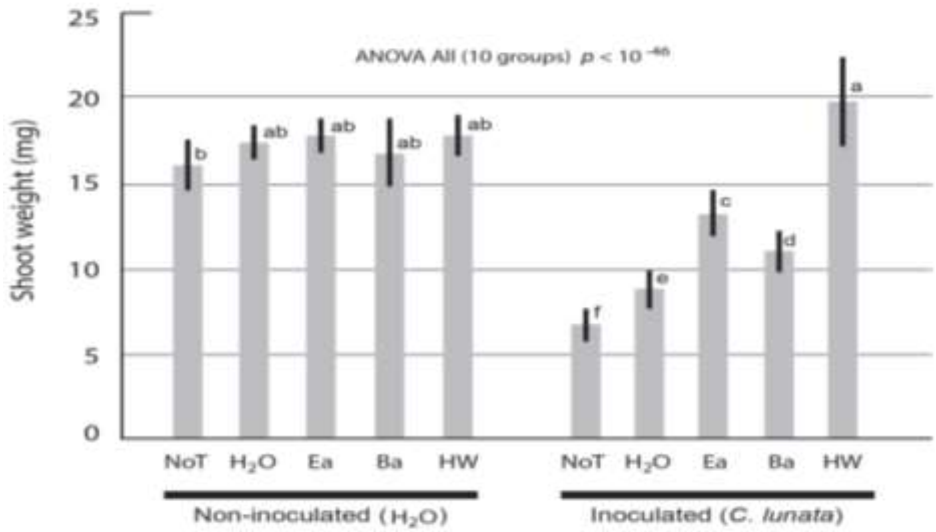

Figure 3. Seedlings growth *in vitro* of artificially inoculated seeds (sample 49.071). Five different treatments: NoT, H_2O, Ea2.5%, Ba2.5% and Hot Water (HW) were compared on seeds inoculated with *C. lunata* or with water (non-inoculated control). For each treatment a total of 2×24 = 48 seeds were tested. Mean shoot dry weight (large bars) and 95% confidence intervals (small bars) are shown. Columns with same letters are not significantly different (Mann Whitney paired test, p< 0.05).

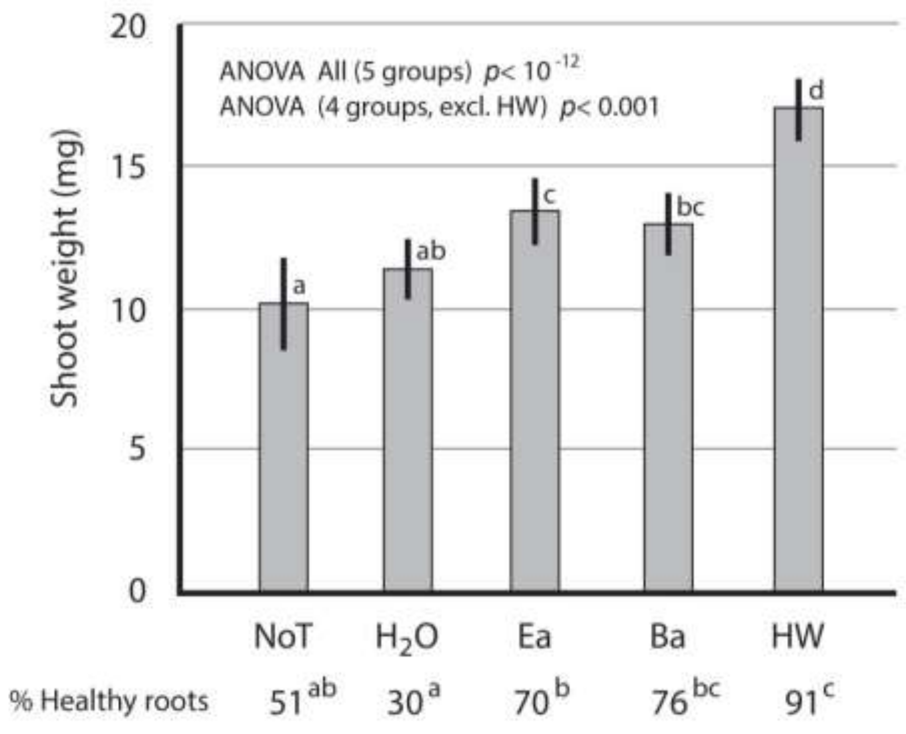

Figure 4. Seedling growth *in vitro* of naturally infected seeds (farm-saved 49.066). Five treatments: NoT, H_2O, Ea2.5%, Ba2.5% and Hot Water (HW) were compared. For each treatment a total of 3×24 = 72 seeds were tested. Mean shoot dry weight (large bars) and 95% confidence intervals (small bars). Columns with same letters are not significantly different (Mann Whitney paired test, p< 0.05). Percentage of healthy roots (absence of dark necrosis) is shown. Groups with same letters are not significantly different (Chi-square test, p<0.05).

Table 4. Rainfall and emergence of farm-saved seeds tested with two plant extracts in three zones.

Zone (Rainfall)	N	Emergence % (means)			ANOVA
		NoT	Ea2.5%	Ba2.5%	
A) Northern (633 mm)	18	63.1	68.5	68.3	ns
B) Central (710 mm)	15	74.8	77.9	79.4	ns
C) South-Eastern (949 mm)	13	63.1	69.5	69.3	ns
Total (direct mean)	46	67.2	72.2	72.1	ns
Total (Field averaged %)	-	95.8	101.7	102.5	$p<0.004$
p-value (paired, NoT)*	-	-	<0.0003	<0.006	-

*Wilcoxon paired test.

Plant extracts tested on farm-saved seeds in three zones

A large scale, participatory field trial was conducted to test the effect of plant extracts on farmers own seeds in their own fields. The trial included 46 farmers distributed in three agricultural zones as shown in Figure 1. The effect of the two extracts was compared to No Treatment. Data were recorded for yield (Table 3), emergence and rainfall (Table 4). An overall significant difference of yield was found between the seed treatments considering all 46 field tests (Total, field average, one-way ANOVA: $p<0.00002$). The overall hierarchy of treatments (effect on yield) was Ba2.5>Ea2.5>NoT. The difference observed between the two plant extracts (all 3 zones) was also significant: p(Ea2.5): $p<0.03$. However, in one zone (C: South-Eastern) comparison of the two extracts turned out to contrast the overall picture: the strongest effect in zone C was observed for *E. alba* extract (+27.7%) compared to *B. aegyptiaca* extract (+22.8%). Note that the same hierarchy of treatments was found when tested on formally produced seeds in the same zone (Table 2). Particularly, the results observed in Zones A and C appeared to be contrasting with regard to the hierarchy of the two plant extracts. Both zones were low yielding (Table 3). Also emergence (No Treatment) was low in both Zones A and C, despite the rainfall being substantially higher in Zone C (Table 4). Note that both plant extracts showed a similar overall effect on emergence (ca +6%). Strongest increases were observed in Zones C and A.

In conclusion, significant effects on yield were obtained for both extracts, but only in the two zones showing low baseline emergence (<65%) and low base line yield (<570 kg/ha). With regard to the effect on yield the overall hierarchy Ba2.5>Ea2.5 was found. However, particularly in zone C, the opposite hierarchy was observed (Ea2.5>Ba2.5) as previously observed using formally propagated seeds.

Antifungal effect on seed mycoflora

The direct antifungal effect of the two plant extracts, Ea2.5% and Ba2.5%, was compared on sorghum seeds carrying a moderate to high natural inoculum (6-40%) of three fungal genera: *Epicoccum*, *Curvularia* and *Fusarium* (Figure 2).

Two repetitions of blotter test show percentage of seeds infected by genera (A) *Epicoccum*, (B) *Curvularia* and (C) *Fusarium*. Each replicate consists of 100 formally produced seeds (Kapelga).

Figure 2 shows that both plant extracts cause inhibition on the genera *Epicoccum* and *Curvularia*, whereas only *B. aegyptiaca* extract inhibits *Fusarium*.

Protection of seedlings from fungal inoculation on seeds *in vitro*

Both plant extracts were compared with respect to their ability to protect seedlings of sorghum from a seed born fungal pathogen, *C. lunata* commonly found on sorghum seeds in Burkina Faso (Zida et al., 2008a; Stokholm et al., 2016). Seeds of variety Kapelga (sample 49.071) were inoculated with either water (control) or the fungus before being treated (NoT, H_2O, Ea2.5%, Ba2.5% and Hot Water (HW)). After treatment seeds were sown on hoagland medium, and shoots of seedlings were analyzed after 16 days (Figure 3).

From Figure 3, it is seen that the pathogenicity of *C. lunata* (inhibition of growth) can to some extent be counteracted by treatment with either of the two plant extracts. The extract from *E. alba* appears as the most protective ($p<0.05$). Both plant extracts are also protective compared to pure water ($p<0.05$). In contrast, no significant differences in shoot weight are found for treatment of non-inoculated seeds with plant extracts.

Protection of seedlings grown from naturally infected, farm-saved seeds

Farm-saved seeds from the village, Diapangou (South-Eastern zone) were tested in seed treatment *in vitro*. Both growth (shoot weight) and seedling health (roots scored for absence of dark necrosis) were recorded (Figure 4).

From Figure 4 it can be seen that with respect to seedling growth, the same hierarchy was observed for farm-saved seeds (naturally infected) as for artificially inoculated seeds above (Figure 3). However, for the two plant extracts only treatment with *E. alba* extract resulted in a significant difference in growth compared to hydropriming (p<0.05). On the other hand, both extracts suppressed development of root necrosis (symptom of fungal infection) significantly compared to hydropriming (p< 0.05).

DISCUSSION

In this study, we have found significant, field averaged yield increases caused by plant extracts of *E. alba* and *B. aegyptiaca*, applied on both farm-saved and formally produced seeds. A yield enhancing effect of both plant extracts was found in comparison to hydropriming. Regional differences in the crop response to seed treatments were observed and significant effects were observed only in two zones (out of three) where the lowest baseline yield and the lowest crop emergence were also found. Tests *in vitro* confirmed the antifungal effect of the two plant extracts both showing inhibition of seed mycoflora and the ability to protect seedlings from seed-borne inoculum of pathogenic fungi.

Water alone: Hydropriming

Hydropriming of seeds is a well-known method to improve yield of crops sown by hand in semi-arid, tropical agriculture (Harris, 2006; Navaz et al., 2013). Yield increases of typically 20 to 30% are observed in several crops, when hydropriming is applied in semi-arid Western Africa (Aune et al., 2017). Specifically in sorghum, the method has been documented several times using soaking times of 8 to 10 h in field trials (Ramamurthy et al., 2005; Aune and Ousman, 2011; Aune et al., 2012; Abdalla et al., 2015). Using 6 h of soaking time, it was recently found that a 19.6% mean increase of sorghum yield could be obtained by hydropriming across three locations (villages) selected for testing in Burkina Faso. The level of yield enhancement by hydropriming found for sorghum in this study appeared to be at the same level (+15.1%, Table 1). No zonal difference in the effect of hydropriming was observed between the two zones B and C compared in Table 2.

Plant extracts and water

Several plant extracts have previously been shown to improve seedling growth and even the yield of sorghum by seed treatment (Raghavendra et al., 2007; Tegegne et al., 2008; Manjunatha et al., 2013; Andresen et al., 2015; Ahmad et al., 2016). In most cases, antifungal activity has been indicated as a possible mechanism of action (Koch and Roberts, 2014). The finding in the present study of an aqueous extract from the bark of *B. aegytiaca* providing a significant yield increase (Ba2.5>H_2O>NoT, Table 1), is to our knowledge, the first demonstration of a specific yield enhancing effect of this plant in a field trial. Although this result was only significant for field averaged values, we consider the conclusion as robust, noting that the absolute levels of yield for non-treated seed varied considerably between individual fields (from 130 to 2800 kg/ha) making statistical treatment of absolute values difficult and strongly prone to a bias from the most high yielding fields. When the subset of data including treatment with *E. alba* extract was stratified into two zones (Table 2) it became apparent that only in the low yielding Zone C, a specific, yield enhancing effect of both plant extracts was observed (Ea>Ba>H_2O>NoT). In this zone, the *E. alba* extract was observed as more efficient (+29%) in comparison to the *B. aegyptiaca* extract (+20%) and hydropriming (+11%). The difference in comparison to hydropriming was significant. For *E. alba,* an additional effect compared to water has been found before in sorghum (Zida et al., 2012, 2015, 2018). However, the present study is the first to test a moderate/low concentration of *E. alba* extract (2.5% w/v) against both non-treated and hydroprimed seeds in parallel under field conditions. In conclusion, when testing formally propagated seeds, a specific effect on yield relative to pure water was found for both plant extracts. The strongest effects were observed in Zone C, which is in agreement with previous findings comparing Kindi (Zone B) and Diapangou locations (Zone C), (Zida et al., 2016).

Farm-saved seeds in three zones

Overall, the participatory trial showed that the initial findings of a significant effect on yield for both plant extracts on formally produced seeds could also beextended to farm-saved seeds (Table 3). Interestingly, the extract from *B. aegyptiaca* was significantly more efficient than the *E. alba* extract (31% compared to 21% yield increase across all zones). The South-Eastern zone (C) appeared as an exception since *E. alba* extract was observed as the most efficient in this zone (Ea: +28%, Ba:+23%) as also observed for formally propagated seeds (Ea: 29%; Ba: 20%, Table 2). Contrarily, in the Northern Zone (A), the observed difference between the two extracts was substantial and in favor of *B. aegyptiaca* (Ea: +18%, Ba: +42%, Table 3). The latter difference was statistically significant. Altogether, our field data were strongly indicative of the existence of regional differences with regard to the seed treatment response and indicated functional biochemical or biological differences between the two plant extracts. Existence of regional/geographical differences for treatment with *E. alba* extract is in good agreement with our previous findings including a low level of emergence found in the zone showing the strongest response (Zida et al. 2016). Interestingly, Zone C showed a low level of emergence and yield despite a relatively high level of rain fall, indicating that biotic factors could play a role (Tables 3 and 4). In the trial with farm-saved seeds, the effect on emergence was almost the same for the two plant extracts, whereas the effect on yield was significantly different. This might indicate that species-specific, biochemical activities of the plant extracts (such as antifungal activity), are having a substantial effect particularly on post-emergence growth of the treated crops.

Results *in vitro*

Antifungal activity has been attributed to both *E. alba* (Abdel-Kader et al., 1998; Saraswathy and Kumaran, 2012; Banaras et al., 2015) and B*. aegyptiaca* (Chapagain et al., 2007; Bonzi et al*.*, 2012). In the present study, results *in vitro* confirmed the antifungal effect of both extracts in two ways.

Mycoflora on seeds:

A reduction of fungi from the genera, *Epicoccum* and *Curvularia*, was repeatedly observed for both extracts on treated seeds (blotter test, >2 fold reduction), whereas no reduction was observed for soaking in pure water (Figure 2). With respect to the genus *Fusarium*, a fundamental difference between the two extracts appeared to exist, since efficient elimination of this genus was observed for *B. aegyptiaca* extract but not for *E. alba* extract (Figure 2).

Effect on seedling growth and health:

Compared to hydropriming, a significant effect of the two plant extracts on growth was only observed for seedlings grown from seeds inoculated with a fungal pathogen. Protection from the pathogen inoculum, *C. lunata*, was most efficiently exerted by the *E. alba* extract (Figure 3). For farm-saved seeds carrying a natural inoculum of fungi (*Epicoccum*, *Curvularia*, *Fusarium*) the frequency of healthy roots (without visible necroses) increased from 30% for soaking in pure water to 70% or more for both plant extracts ($p<0.05$).

In conclusion, both mycoflora on seeds and symptoms caused by fungal inoculum on seeds could be reduced by treatment with the plant extracts. Some differences appeared to exist between the two plant extracts with regard to inhibition of *Fusarium* and protection from *C. lunata*.

Perspectives

The finding that treatment of farm-saved seeds with either of two antifungal plant extracts leads to overall, significant yield increases is encouraging for proceeding towards implementation of the technology in Burkina Faso. It is further encouraging that both plant species are commonly found in the regions where their activity appears to be optimal, respectively (*E. alba* in South-East; *B. aegyptiaca* in the North). *E. alba* is already well known to farmers due to its medicinal characteristics and no acute toxicity of an extract from *E. alba* leaves was found in a recent study (Udayashankar et al., 2016). With regard to the *E. alba* extract implementation in the South-Eastern zone therefore appears to be straight forward. With regard to *B. aegyptiaca* the somewhat surprising finding of a 42% yield increase on farmers' fields in the Northern region strongly encourages a focus on implementing the use of this extract in the Northern region where the desert tree, *B. aegyptiaca*, is also commonly found. However, careful consideration should be made regarding a safe protocol for obtaining the bark powder without killing the tree leading to unintended deforestation. More research into the differences between low-yielding/dry versus low-yielding/humid zones on the importance of hydropriming and yield loss caused by different ascomycetes seems justified by the present observations of a difference in crop response to treatments. Local seeds should be given a high priority in such research. In addition, experiments to domesticate *E. alba* and *B. aegyptiaca* by farmers could be initiated to increase the feasibility of sampling botanical material.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests

ACKNOWLEDGEMENT

The technical assistance of Séni Bilgo, Solange Zida and Marcellin Tiemtoré is gratefully acknowledged and thank the European Union for the grant n° DCI-FOOD/2012/304-690 under the Europe AID program: Increasing yields of Sorghum and Millet by a new and sustainable seed technology developed in Sahel. The authors further thank the "Fonds National de la Recherche et de l'Innovation pour le Développement (FONRID)'', the "Organisation Africaine de la Propriété Intellectuelle (OAPI)" and the National Extension Service in Burkina Faso for the grant n° AP3/PC 005/12/2013, the grant n° 54/14 and for fruitful collaboration.

REFERENCES

Abdalla EA, Osman AK, Maki MA, Nur FM, Ali SB, Aune JB (2015). The response of sorghum, groundnut, sesame and cowpea to seed priming and fertilizer micro-dosing in South Kordofan. Agronomy 5:476-490.

Abdel-Kader MS, Bahler BD, Malone S, Werkhoven MC, van Troon F, Wisse JH, Bursuker I, Neddermann KM, Mamber SW, Kingston DG (1998). DNA-damaging steroidal alkaloids from *Eclipta alba* from Suriname rainforest. Journal of Natural Products 61:1202-1208.

Ahmad W, Noor MA, Afzal I, Bakhtavar MA, Nawaz MM, Sun X, Zhou B, Ma W, Zhao M (2016). Improvement of sorghum crop through exogenous application of natural growth-promoting substances under changing climate. Sustainability 8:1330.

Andresen M, Wulff EG, Mbega ER, Stokholm MS, Glazowska SE, Zida EP, Mabagala RB, Lund OS (2015). Seed treatment with an aqueous extract of Agave sisalana improves seed health and seedling growth of sorghum. European Journal of Plant Pathology 141:119-132.

Arbonnier M (2002). Arbres, arbustes et lianes des zones sèches d'Afrique de l'Ouest, 2[è] Edits CIRAD – UICN, 574 p.

Aune JB, Coulibaly A, Giller KE (2017). Precision farming for increased land and labour productivity in semi-arid West Africa: Review. Agronomy for Sustainable Development 37:16.

Aune JB, Traoré CO, Mamadou S (2012). Low-cost technologies for improved productivity of dryland farming in Mali. Outlook on Agriculture 41:103-108.

Aune, JB, Ousman A (2011). Effect of seed priming and micro-dosing of fertilizer on sorghum and pearl millet in Western Sudan. Experimental Agriculture 47:419-430.

Banaras S, Javaid A, Iqbal SM (2015). use of methanolic extracts of an asteraceous weed *Eclipta alba* for control og macrophomina phaseolina. Pakistan Journal of Weed Science Research 21:101-110.

Begum S, Lee MR. Gu LJ, Hossain J, Sung CK (2015). Exogenous stimulation with *Eclipta alba* promotes hair matrix keratinocyte proliferation and downregulates TGF-β1 expression in nude mice. International Journal of Molecular Medicine 35:496-502.

Bhalerao SA, Verma DR, Teli NC, Murukate VR (2013). *Eclipta alba* (L): AN OVERVIEW. International Journal of Bioassays 2:1443-1447.

Bonzi S, Somda I, Zida E, Sérémé P (2012). Efficacy of plant extracts and effect of seed soaking duration on treatment of sorghum seed naturally infected by Colletotrichum graminicola and Phoma sorghina. Arch. Phytopathol. Plant Protection 45(12):1405-1410.

CABI (2018). Invasive Species Compendium. Online: https://www.cabi.org/isc/datasheet/20395.

Chapagain BP, Wiesman Z, Tsror L (2007). *In vitro* study of the antifungal activity of saponin-rich extracts against prevalent phytopathogenic fungi. Industrial Crops and Products 26:109-115.

Chothani DL, Vaghasiya HU (2011). A review on *Balanites aegyptiaca* Del (desert date): phytochemical constituents, traditional uses, and pharmacological activity. Pharmacognosy Review 5:55-62.

De Longueville F, Hountondji YC, Kindo I, Gemenne F, Ozer P (2016). Long-term analysis of rainfall and temperature data in Burkina Faso (1950-2013). International Journal of Climatology 36:4393-4405.

GBIF (2018). Global Biodiversity Information Facility: https://www.gbif.org (accessed 24 Aug. 2018).

Hammer Ø, Harper DAT, Ryan PD (2001). PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1): 9pp. On-line software version 3.20 available on https://folk.uio.no/ohammer/past/.

Harris D (2006). Development and testing of "On-farm" seed priming. Advances in Agronomy 90:129-178.

Holm LG, Plucknett DL, Pancho JV, Herberger JP (1977). The World's Worst Weeds. Distribution and Biology. Honolulu, Hawaii, USA: University Press of Hawaii.

Institut National de la Statistique et de la Démographie (INSD) Burkina Faso (2016). Annuaire Statistique National 2015, On-line Publication: http://www.insd.bf.

Jahan R, Al-Nahain A, Majumdder S, Rahmatullah M (2014). Ethnopharmacological significance of *Eclipta alba* (L.) Hassk. (Asteracea). International Scholarly Research Notices, 2014, 385969. http://doi.org/10.1155/2014/385969.

Koch E, Roberts SJ (2014). Non-chemical seed treatment in the control of seed-borne pathogens. *In*: Global Perspectives on the Health of Seeds and Plant Propagation Material Volume 6 of the series Plant Pathology in the 21st Century, Springer Nature pp. 105-123.

Manjunatha HP, Singh H, Chauhan JB, Zameer F, Garampalli RH (2013). Induction of resistance against sorghum downy mildew by seed treatment with Duranta repens extracts. IOSR J Agriculture and Veterinary Science 3:37-44.

Mathur SB, Kongsdal (2003). Common Laboratory Seed Health Testing Methods for Detecting Fungi. ISTA, Basserdorf, CH-Switzerland 425 p.

Navaz J Hussain M, Jabbar A, Nadeem GA, Sajid M, Subtain MU, Shabbir I (2013). Seed Priming: A technique. International Journal of Agriculture and Crop Sciences 6:1373-1381.

Prom LK, Waniska RD, Kollo AI, Rooney WL (2003). Response of eight sorghum cultivars inoculated with Fusarium thapsinum, Curvularia lunata, and a mixture of the two fungi. Crop Protection 22:623-628.

Raghavendra VB, Govindappa M, Lokesh S, Vasanthkumar T (2007). Dravya—As an organic agent for the management of seed-borne fungi of sorghum and its role in the induction of defense enzymes. Pesticide Biochemistry and Physiology 89:190-197.

Ramamurthy V, Gajbhiye KS, Venugopalan MV, Parhad VN (2005). On-farm evaluation of seed priming technology in sorghum (*Sorghum bicolor* L.). Agricultura Tropica et Subtropica 38:34-40.

Saraswathy N, Kumaran PM (2012). Evaluation of aqueous extract of *Eclipta alba* leaves for preservative potential against Fusarium species. American Journal of PharmaTech Research 5:647-649.

Schémaeza B, Somda, Zida E, Paco S (2012). Efficacy of plant extracts and effect of seed soaking duration on treatment of sorghum seed naturally infected by *Colletotrichum graminicola* and *Phoma sorghina*. Archives of Phytopathology and Plant Protection 45(12):1405-1410.

Schmidt M, Kreft H, Thiombiano A, Zizka G (2005). Herbarium collections and field data-based plant diversity maps for Burkina Faso. Diversity and Distributions 11:509-516.

Stokholm MS, Wulff EG, Zida EP, Thio IG, Néya JB, Soalla RW, Głazowska SE, Andresen M, Topbjerg HB, Boelt B, Lund OS (2016). DNA barcoding and isolation of vertically transmitted ascomycetes in sorghum from Burkina Faso: *Epicoccum sorghinum* is dominant in seedlings and appears as a common root pathogen. Microbiological Research 191:38-50.

Tegegne G, Pretorius JC, Swart WJ (2008). Antifungal properties of *Agapanthus africanus* L. extracts against plant pathogens. Crop Protection 27:1052-1060.

Udayashankar AC, Rajini SB, Nandhini M, Suhas YS, Niranjana SR, Lund OS, Prakash HS (2016). Acute oral toxicity, dermal irritation and eye irritation study of *Eclipta alba* aqueous extract in Sprague dawley rats and Newzealand white rabbits. International Research Journal of Pharmacy 7:103-109.

Zida EP, Lund OS, Néya JB (2012). Seed treatment with a binary pesticide and aqueous extract of *Eclipta alba* (L.) Hassk. for improving sorghum yield in Burkina Faso. Journal of Tropical Agriculture 50:1-7.

Zida PE, Néya BJ, Soalla WR, Prakash HS, Niranjana SR, Udayashankar AC, Nandini M, Rajini SB, Barrocas EN, Andresen M, Sérémé P, Lund OS (2015). Increased feasibility of treating sorghum seeds with *Eclipta alba* extract by lowering concentration of plant extract and soaking time of seeds. International Journal of Tropical Agriculture 33:2391-2400.

Zida PE, Néya BJ, Jensen SM, Soalla WR, Sérémé P, Lund OS (2018). Increasing sorghum yields by seed treatment with an aqueous extract of the plant *Eclipta alba* may involve a dual mechanism of hydropriming and suppression of fungal pathogens. Crop Protection 107:48-55.

Zida PE, Néya BJ, Soalla WR, Jensen SM, Stokholm MS, Andresen M, Kabir MH, Sérémé P, Lund OS (2016). Effect of sorghum seed treatment in Burkina Faso varies with baseline crop performance and geographical location. African Crop Science Journal 24:109-125.

Zida PE, Sérémé P, Leth V, Sankara P, Somda I, Néya A (2008a). Importance of seed-borne fungi on sorghum and pearl millet in Burkina Faso and their control using plant extracts. Pakistan Journal of Biological Sciences 11:321-331.

Zida EP, Sérémé P, Leth V, Sankara P (2008b). Effect of aqueous extracts of *Acacia gourmaensis* A. Chev. and *Eclipta alba* (L.) Hassk. on seed health, seedling vigour and grain yield of sorghum and pearl millet. Asian Journal of Plant Pathology 2(1):40-47.

Vol. 13(44), pp. 2526-2541, 1 November, 2018
DOI: 10.5897/AJAR2018.13428
Article Number: FCE4A0A59121
ISSN: 1991-637X
Copyright ©2018
Author(s) retain the copyright of this article
http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Estimating of rainfall soil losses in Oltu Anzav Watershed

Metin Demir[1], Adnan Bilgili[2] and Turgay Dindaroğlu[3*]

[1]Department of Landscape Architecture, Faculty of Architecture and Design, Atatürk University, 25240 Erzurum, Turkey.
[2]Eastern Anatolia Forestry Research Institute, 25050 Erzurum, Turkey.
[3]Department of Forest Engineering, Faculty of Forest, Kahramanmaraş Sütçüimam University, 46100 Kahramanmaraş, Turkey.

Received 31 July, 2018; Accepted 15 October, 2018

Erosion is a key factor for sustainability of land management. This study aimed to determine the spatial distribution of estimated total soil loss amount and erosion severity in the Oltu Anzav Watershed located in the East of Anatolia, Turkey. This study was conducted by using Geographical Information Systems (GIS) based on Revised Universal Soil Loss Equation (RUSLE) method. Topsoil samples (0-30 cm) were collected in 129 sites and analyzed for soil erosivity factor (K). Furthermore, the spatial distribution of potential estimated soil losses that may occur was mapped with the modeling using different scenarios in the future. Five different erosion risk groups have been determined as slight, moderate, severe, very severe and extreme, in the watershed area. As a result, the average surface soil loss was estimated as 24.44 ton ha^{-1}year^{-1}. Also, two different scenarios were created to estimate soil losses in the future in this study. According to the first scenario, if rehabilitation processes are implemented in the degraded forest area, soil loss was estimated as 7.33 tones ha^{-1}year^{-1}. In the second scenario, if any measures are not taken for soil erosion and flood control, soil loss was estimated as 58.63 ton ha^{-1}year^{-1}. Finally, sedimentation should be reduced in the watershed by erosion and flood control projects and applications.

Key words: Erosion, erosion risk maps, Anzav basin, revised universal soil loss equation (RUSLE), geographical information systems (GIS).

INTRODUCTION

Soil erosion is one of the most serious environmental problems in Turkey and in the world. Due to the effects of unconscious human activities, the problem is increasing day by day (Yuksel et al., 2007; Karabulut and Kuçukonder, 2008; Ozsahin and Keles, 2016).

It is estimated that the half of total land areas are affected by serious erosion problem in Turkey (CEMGM, 2018). Moreover, industrial and residential centers are increasing in productive agricultural lands, and agricultural activities are shifting towards sloping areas.

*Corresponding author. E-mail: turgaydindaroglu@hotmail.com Tel.: +90 (344) 300-1815.

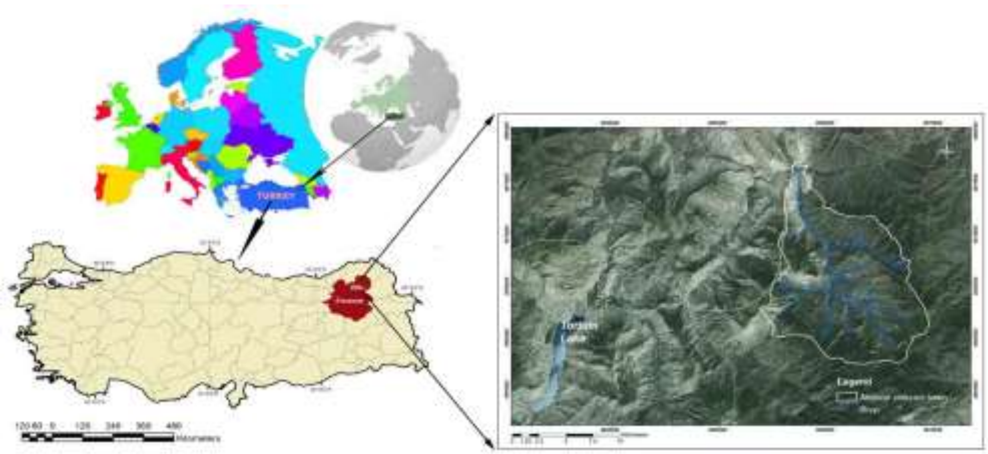

Figure 1. Location of the research area.

The results of poor land management practices causes an increase in erosion problems and destroys the natural balance of soil. This deterioration can cause many problems directly or indirectly, such as deterioration of river regimes, disappearance of wetlands, shortening of reservoir life, sediment accumulation in agricultural lands, increase of flooding events and water pollution (Karabulut and Kucukonder, 2008; Zengin et al., 2009; Aydin, 2009; Bouaziz et al., 2011; Sonmez et al., 2013).

Investigation of the size of the problem is essential in erosion control, and precautions and monitoring the process is very important for sustainable land management. Effective soil erosion assessments helps not only to determine the spatial distribution of the soil loss risks but also to develop and practice regional policies to reduce soil losses. For this purpose, numerous erosion/soil loss estimation methods have been developed. Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation (RUSLE), and Institute for Conservation of the Nature (ICONA) equations are the most commonly used methods (Renard et al., 1997; Tagil, 2007; Karaoglu, 2012).

Geographic Information Systems (GIS) is one of the most important means of analyzing, mapping and monitoring the erosion problem.

The aim of this study is to estimate and map the spatial variation of the current annual soil loss amount of Oltu Anzav Basin. It is also aimed to estimate and map the spatial variation of potential annual land loss amounts as a result of two different scenarios.

MATERIALS AND METHODS

This research was carried out in Anzav Basin of the Oltu town, located in the south of Erzurum province, Turkey. The coordinates of the study area are 40°43'48'' to 40°41'24'' N and 41°49'48'' to 41°53'24'' E (Figure 1). The total area of the basin is 10.017 ha. Anzav Basin and its vicinity is covered with volcanic and sedimentary basic rocks formed during the Jurassic-Cretaceous period. Clastic and carbonate rock formed during the Upper Jurassic-Lower Cretaceous period (MRE, 2018).

Climate of the study area is generally cold and temperate. According to Thornthwaite climate classification, it is classified as semi-arid, less humid climate type. The average temperature is 9.1°C and the average annual rainfall is 426 mm (MGD, 2018).The sampling points were determined according to the factorial design, taking into consideration of bedrock, large soil groups, slope, aspect, altitude and land use situations. For this purpose, degraded surface (0-30 cm) soil samples were taken from 129 points (Figure 2). Topography maps, with 1/25.000 scale of the study area were digitized in ArcGIS program, in order to produce the slope and slope length maps used as parameters in the study (Figure 3).

The altitude of the research area varies between 730 m and 2890 m, and a total of 8 elevation groups were determined taking into consideration vegetation and usage, resulting from the elevation changes (Figure 4 and Table 1).

Revised Universal Soil Loss Equation (RUSLE) was used to estimate annual soil loss in research area (Wischmeier and Smith, 1978; Williams and Bernth, 1972; Renard et al., 1997; Ekinci, 2007; Ozsahin, 2014; Celik, 2011). RUSLE equation is as follows (1).

$$A=R*LS*C*K*P \qquad (1)$$

Where;
A = annual soil loss from sheet and rill erosion in tons acre-1
R = rainfall erosivity factor
K = soil erodibility factor
LS soil erodibility factor = slope length and steepness factor
C = cover and management factor
P = support practice factor

The determined value in the equation refers to the amount of potential soil loss in any selected area that will most likely be caused by groove erosion. Rainfall data, topographic data, soil characteristics, land cover and soil protection measures of the study

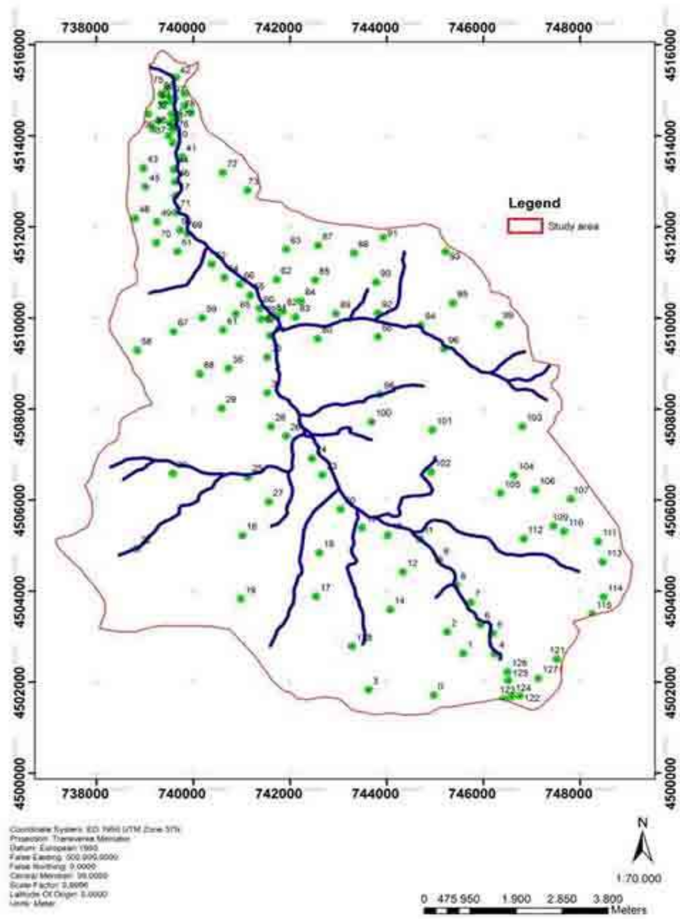

Figure 2. Soil sampling points.

area are used as an input dataset.

Rainfall erosivity factor (R)

Rainfall is the main component and factor of erosion wherever water erosion is seen. The R factor is accepted as the potential erosivity of flowing water or a measure of the erosive force and intensity of rain in a normal year; also, it is greatly affected by the intensity and duration of rain and diameter, mass, and velocity of raindrops (Wischmeier and Smith, 1978).

Slope length and stepness factor (LS)

Slope length and steepness (LS) factor is another important factor in the soil transport and it is a measure of sediment production. The following Equation 2 was used to calculate the LS factor (Williams and Bernth, 1972).

$$LS\,(r) = (m+1)\left[A(r)/a_0\right]^m \left[\sin b(r)/b_0\right]^n \qquad (2)$$

A(r): The upper slope, contributes to the width of each contour curves; b(r): Slope in degrees, m and n parameters: Experimentally determined as 0.4 and 1.4 respectively; a0: (22.1 m = 2.6 ft) length; b0: (0.09 = 9% = 5.16°) the slope of standard USLE pilot. The flow directions and flow accumulation maps were produced in the Archydro in raster format using SYM to calculate the slope degree and slope length factor.

The slope map of the same area was produced in raster format in degrees using the "3D Analyst" module. The above formula was arranged as follows in Equation 3 and LS factor was calculated using ArcGIS "Map Algebra". The map resolution was 58 m in this study.

LS=Power ("Fac"*58/22.1,0.4)*Power(Sin("slopedegree"*0.01745)/0.09,1.4)*1.4 (3)

Soil erodibility factor (K)

According to Balci (1996), erodibility represents resistance to erosive forces and erosion caused by various soil properties. It is a

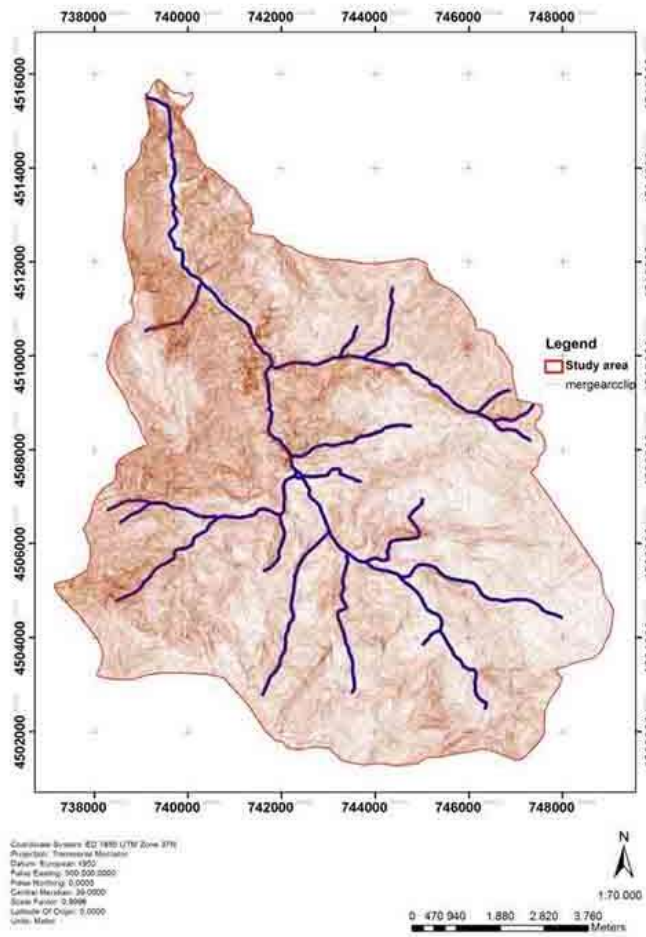

Figure 3. Contour curves.

measure of the sensitivity of soil particles to erosion and transport by the influence of precipitation and flow. The soil erodibility is largely due to the physical and chemical properties of the soil. In other words, it depends on texture and structure of the soil. While some soils are resistant to the same erosive forces, some soils are easily dissolved, dispersed, and exposed to erosion. Texture and structure properties of soil, organic matter content, and hydraulic conductivity are the leading factors that affect soil erosion (Figure 5, Table 2).

In order to calculate factor K in 129 soil samples, soil organic matter, soil particle size (Bouyoucos, 1962) and fine sand quantities were determined by laboratory analysis and K factors were determined using these values, with the help of the above nomogram.

Crop management factor (C)

The vegetation type, age and coverage ratio are used to estimate soil losses because they directly affect the erosivity of the rain (Canga, 1995; Irvem and Tulucu 2004). The C factor for the study area was determined using forest management maps and land presence maps.

Soil conservation practice factor (P)

In RUSLE module, the soil conservation practice factor (P) represents the ratio of the soil loss in the direction of slope with a special support application to the soil loss caused by soil tillage. These applications affect erosion by altering the type, size or direction of the surface flow, or by reducing the amount and speed of surface flow (Renard et al., 1997).

Erosion classification

The erosion classification map of the basin was constructed according to Uzunsoy and Gorcelioglu (1985) classification (Table 3).

RESULTS AND DISCUSSION

The high slope values of the research area caused some events such as erosion and landslide on the slopes,

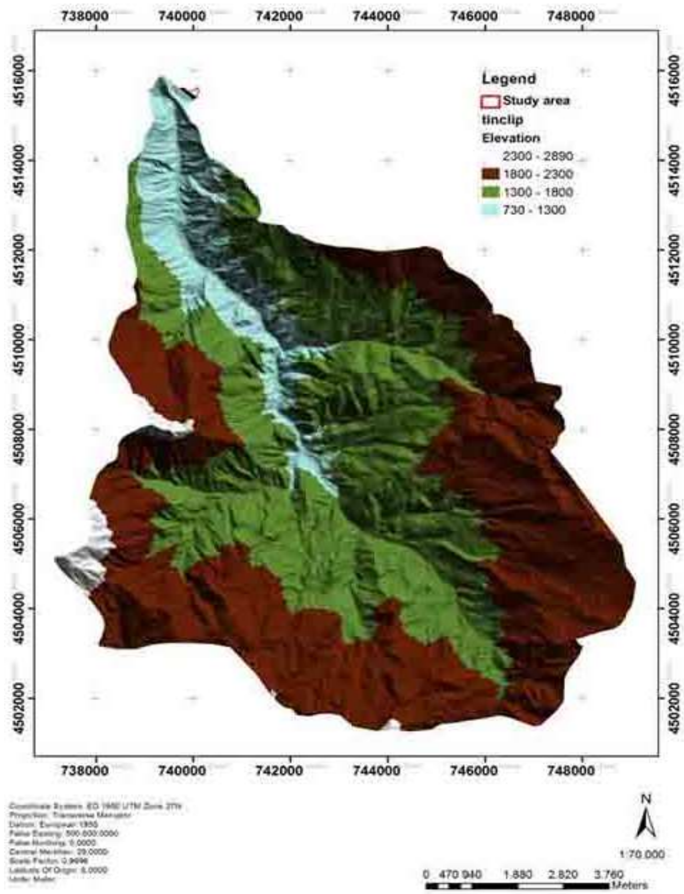

Figure 4. Spatial distribution of elevation

Table 1. Elevation groups of the research area.

Elevation groups (m)	Area (ha)	Rate %
750-1000	341.85	3.41
1000-1250	463.44	4.63
1250-1500	1359.67	13.57
1500-1750	2223.01	22.19
1750-2000	2635.40	26.31
2000-2250	2684.80	26.80
2250-2500	172.28	1.72
2500+	136.77	1.37
Total	10017.21	100

which causes soil abrasion and transport processes to continue actively. The research area has young geomorphological formation appearance, divided by deep valleys. The limited agricultural activities that can be done on the accumulations in the valley bases are one of the most important factors determining the social and economic structure of the region (Yarbasi, 2016).

The slope map was constructed from the Digital Elevation Model (DEM) map (Figure 6). The distribution and proportions of the slope groups in the area are given

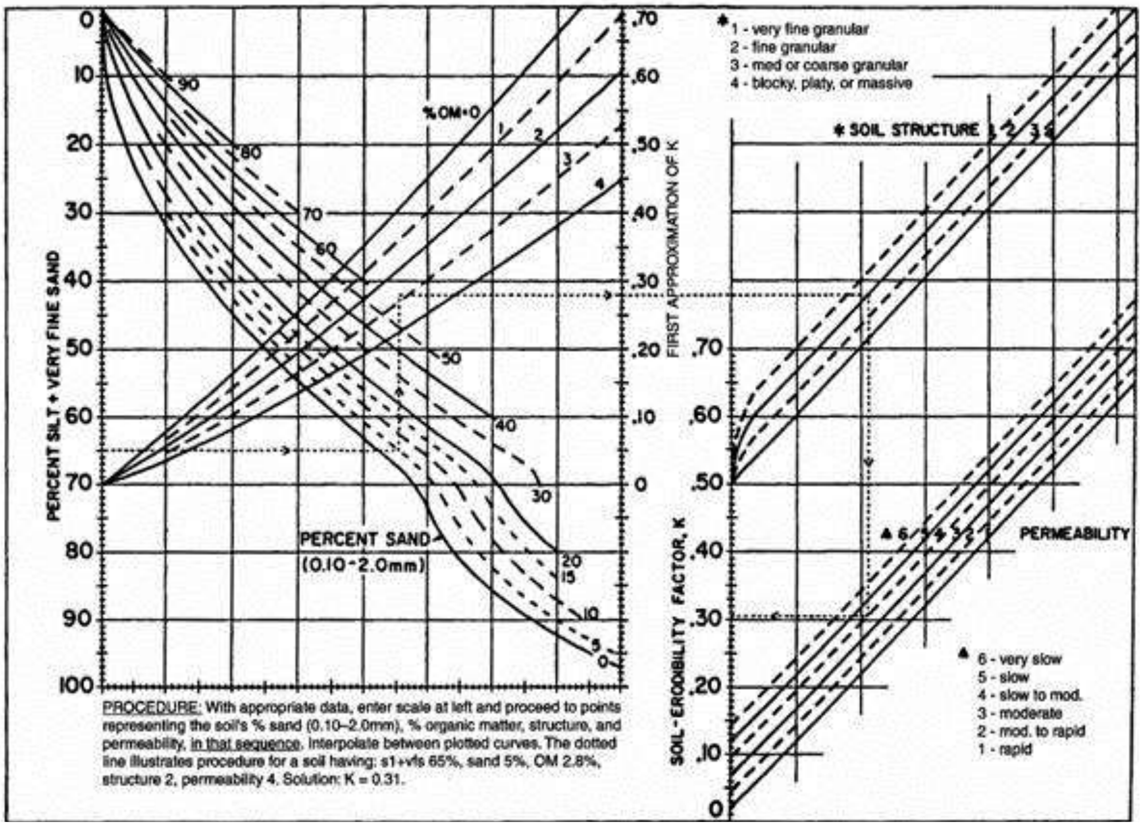

Figure 5. Soil erosion factor (K) nomography.

Table 2. Classification of the soils according to the factor "K".

Factor K	Erodibility
0-0.05	Very low
0.05-0.10	Low
0.10-0.20	Moderate
0.20-0.40	Strong
0.40-0.60	Very Strong

Table 3. Erosion classification system.

Erosion class	Name	Definition
0	No erosion	No erosion or negligible level
1	Light erosion	0-25% of soil moved
2	Moderate-severe erosion	25-75% of upper soil moved
3	Severe erosion	75-100% of upper soil moved
4	Very severe erosion	Whole upper soil, 25-75% of lower soil moved
5	Extremely severe erosion	Whole upper soil, more than 75% of lower soil moved

Table 4. The slope groups of the research area.

Slope groups	Area (ha)	Rate %
0-5	183.42	1.83
5-15	2329.99	23.26
15-30	5349.88	53.41
30-60	1978.12	19.75
60+	175.79	1.75
Total	10017.21	100

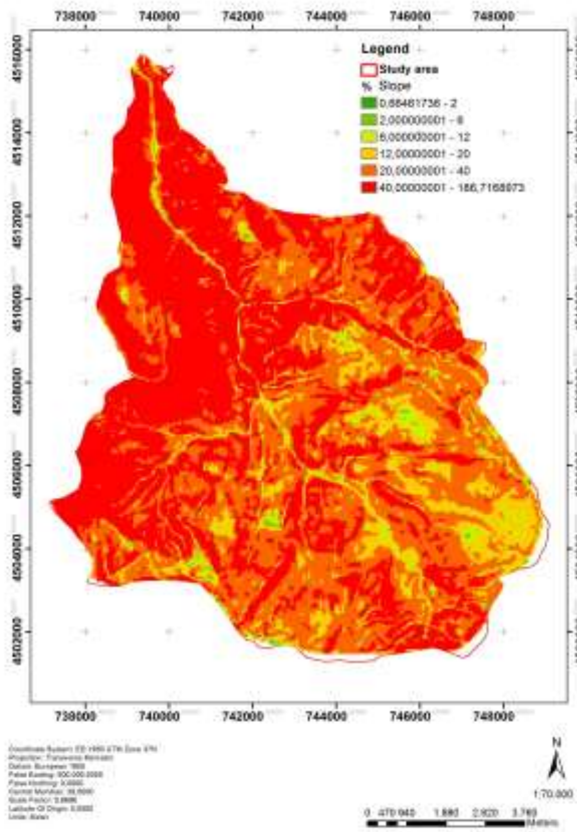

Figure 6. Slope map.

in Table 4. Accordingly, over 75% of the research area is above 1500 m elevation. At the same time, 75% of the area is included in steep and very steep slope group. This situation shows that the area has very extreme features in terms of physiographic characteristics. In this study, factor R-value used was determined by CEM (2016). The factor R-value was determined as 249.13 (Figure 7).

Slope length and steepness factor (LS)

The highest LS value of the basin was determined as 16.51 (Figure 8). Pictures showing the general physiographic condition of the basin are presented in Figure 9. Ozdemir and Tatar (2016) determined the value of the LS factor from 0 to 37.38 in the Isıklı Watershed, Turkey.

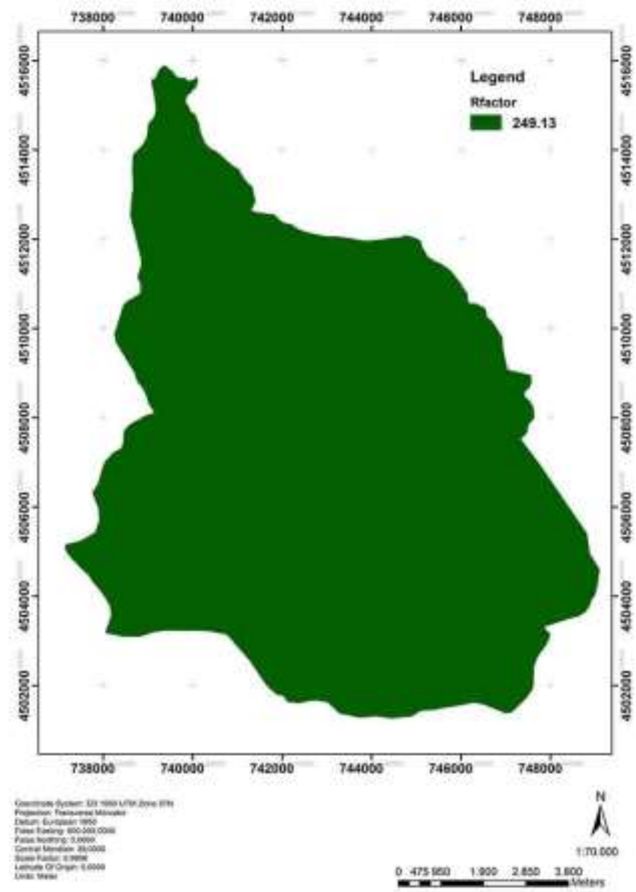

Figure 7. Map of "R" factor.

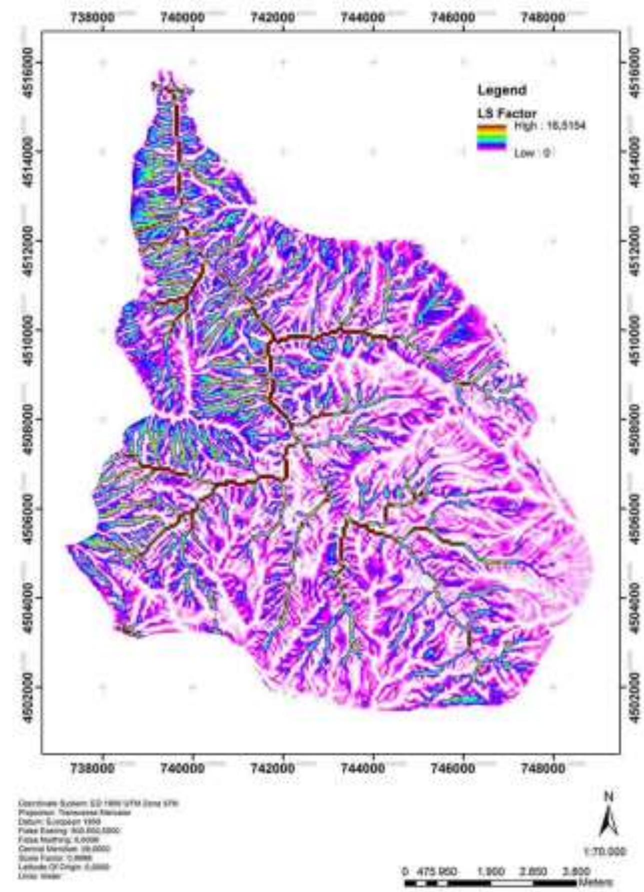

Figure 8. Map of "LS" factor.

Soil erodibility factor (K)

The map constructed for the factor K in the study basin are shown in Figure 10, and the spatial distributions of the factor K values are shown in Table 5. According to the results obtained, 85.46% of the study area has strong erodibility potential. This situation indicates that plant management factor (C) and soil protection measures (P) have a determinative role for the soil losses in this area.

Crop management factor (C)

Up to 2,200 m yellow pine forest is common in the basin, and above 2,200 m level the European-Siberian origin plants are spread (Atalay, 2008). The vegetative situation in the research area was determined using the forest management plans and actual land cover maps; the factor C values used in predicting the abrasive effect of rainfall such as vegetation type, age and coverage rate, were determined using the values obtained by Canga (1995) and Atalay (2008). The C factor values map generated at this stage of the research (Figure 11) and the spatial and proportional distributions obtained from the corresponding maps are shown in Table 6. Approximately, 75% of the basin is lacking in the protection ability of plants.

Soil conservation support practice factor (P)

Protective measures are necessary to prevent soil losses directly or indirectly. However, generally in this basin, there was no application for erosion control. General Directorate of State Hydraulic Works (DSI) built some barriers in the valley, however, the P factor was not evaluated since this situation could not be identified as the measures that prevent sediment transport into the

Figure 9. Some photos of slope length in the research area

valley within the basin (Figure 12).

Estimation of soil loss amounts

The layer of each factor obtained was multiplied in the GIS program, and consequently the potential soil loss of the Oltu Anzav Basin was determined as ton $ha^{-1}year^{-1}$. When examined, the distribution map of potential erosion risk classes (Figure 13), especially in the geomorphologically narrow regions of the basin and in the collected areas of drainage lines, too much soil losses occur due to the decrease in plant density and low soil losses are observed in the upper parts of the basin with lower slope. According to the results of the research, the average actual soil loss of the basin was estimated as 24.45 t $ha^{-1}year^{-1}$. Tufekcioglu and Yavuz (2016) have conducted a research in Artvin province, close to our study area, and found the surface erosion soil loss as an average of 3.60 t ha-1 $year^{-1}$. Different results under similar climatic and topographic conditions within the same basin are closely related with the variable K, C and P factors. A study conducted by Karakas (2005) have shown that while the annual soil was estimated as 0-5 ton ha^{-1} in Kuçukelmali Basin, it was determined as 0-15 ton ha^{-1} for Guvenc Basin, which are located in Sakarya River Basin. The annual soil loss was estimated as 0-75 ton ha^{-1} for Bolvadin/Degirmendere Basin (Celik, 2011). The annual soil loss for the region known as Ilgaz Mountain-Indagı Pass in Cankiri province was estimated as 0-15 ton ha^{-1} (Basaran, 2005). A study conducted by RUSLE method on Dudhawa Basin by Sahu et al. (2017) have shown that there is much more less than 5 ton ha^{-1} soil loss in 90% of the basin. Meghraoui et al. (2017) have estimated the annual soil loss as 150-200 t ha^{-1} in Sabaa Chioukh Mountains. Annual soil loss in Muhirapuzha River Basin was found as 3.60 t ha^{-1} in a study conducted by Thomas et al. (2017). Differences in the determination of results have shown that factors that causes soil loss in RUSLE methods differs from basin to basin. Since losses are calculated annually, the changes in land use directly affect these losses.

Kumar and Kushwaha (2013) determined the average loss of soil in the Shivalik Hills as 35.47 t $ha^{-1}year^{-1}$. They determined this value as 8.50 t $ha^{-1}year^{-1}$ in areas with very dense forest cover and as 134.9 t $ha^{-1}year^{-1}$ in degraded forest or bare areas. A study conducted by Molla and Biniam (2016) in Koga Watershed, Highlands of Ethiopia, showed that the annual average soil loss rate was 30.2 t $ha^{-1}year^{-1}$.

According to this classification system, in areas where erosion is not observed or erosion is seen as low,

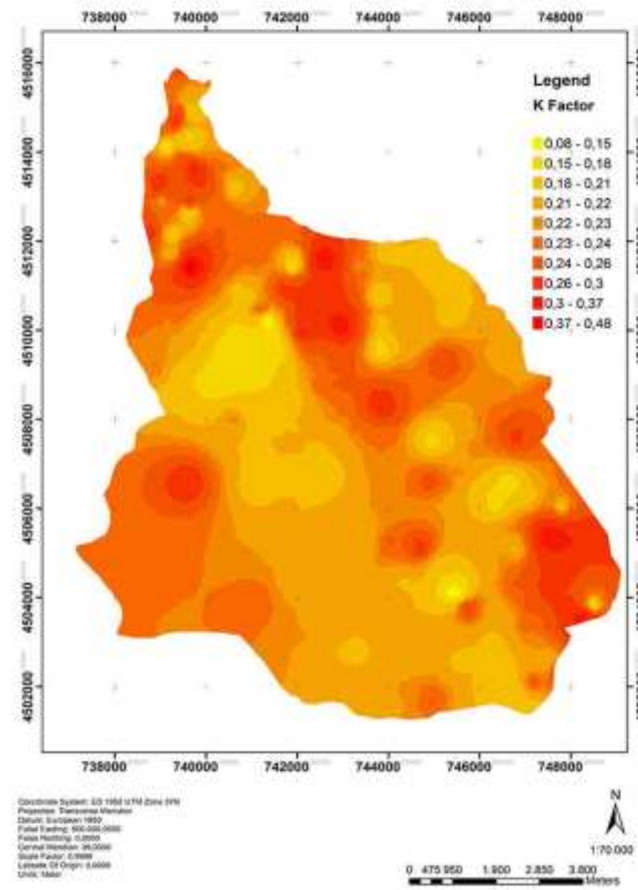

Figure 10. Spatial distribution of "K" factor.

moderate, severe, very severe and extremely severe erosion, their coverage areas and distributions were investigated and the annual amount of total soil loss in the basin was estimated approximately. The erosion images of the study area are presented in Figure 14.

Modeling of two different hypothesized scenarios in the research basin

By analyzing the data that belong to all the factors needed in the GIS-based RUSLE method, potential soil losses that could occur have been estimated by modeling of two different scenarios such as rehabilitating the current forest areas in the basin and taking no precautions. Depending on the situation of rehabilitation of forest areas, afforestation of degraded forest areas was foreseen, and according to this case the factor C was recalculated and the soil loss maps were constructed as in Figure 15.

In case of no precautions taken in the basin, assuming that the damaged forest areas will be completely bare, the map of soil losses that can be constructed by re-calculating the C factor is shown in Figure 16. The spatial and proportional distributions of soil loss estimates, dealing with the current situation and the other two scenarios were given in Table 7.

On the other hand, in case of rehabilitation of the forest areas in the basin, it is estimated that slight severe erosion could occur in 50.40%, moderate severity in 17.33%, severe in 8.92%, very severe in 10.21%, and extremely severe erosion in 13.15% of total area (Tables 7). In case of rehabilitation of degraded forest ecosystems, the average soil loss is estimated to decrease from 24.45 to 7.33 ton ha^{-1} (Tables 8). For this reason, rehabilitation projects should be implemented as soon as possible in the region. Terranova et al., (2009) emphasized that within the scope of protective land management, soil loss has decreased from 30 to 12.3 Mg^{-1}ha^{-1} due to measures and application to reduce soil losses as cause of water erosion in southern Italy. A study conducted with RUSLE method by Ettazarini et al. (2017) in Argana Basin of Morocco has shown that almost 82.77% of the basin is under severe erosion. Differences in factors that play active role in soil loss cause different results. The important thing is to implement the proper methods in the field to reduce these effects.

According to the scenarios, if no precautions are taken (if the grazing activities continue, and current degraded forest areas become completely bare), it is estimated that slight severe erosion could occur in 31.76% and very severe erosion may occur in 68.24% of the study area (Table 7). Finally, it is also estimated that the average soil loss in the basin could be increased from 24.45 to 58.64 ton ha^{-1}year^{-1} (Table 8).

Field observations made in the research area and the studies conducted in the basin, has shown that the floods occur frequently in the research area and basin and this situation causes damages in agricultural land, animals and barns.

As the basin has generally steep structure, the soil has been transported by surface flow, and in some areas the bedrock has been surfaced. Productive forests and enough vegetation cover in some areas of the research basin can relatively reduce the damage that may occur. However, livestock, which is the main source of livelihood in the basin, causes grazing pressure in degraded forests. Due to this heavy and incorrect land use in the basin, the vegetation has been severely damaged and the soil has become extremely sensitive to erosion.

This high amount of soil transport demonstrates the importance of rehabilitation projects which should be planned in the basin (Table 8).

Table 5. Spatial distribution of factor K values of research area.

Factor K values	Spatial distribution	Rate %
0-0.05	0.27	0.00
0.005-0.1	0.69	0.01
0.1-0.2	1452.21	14.50
0.2-0.4	8560.92	85.46
0.4-0.6	3.11	0.03
Total	10017.21	100.00

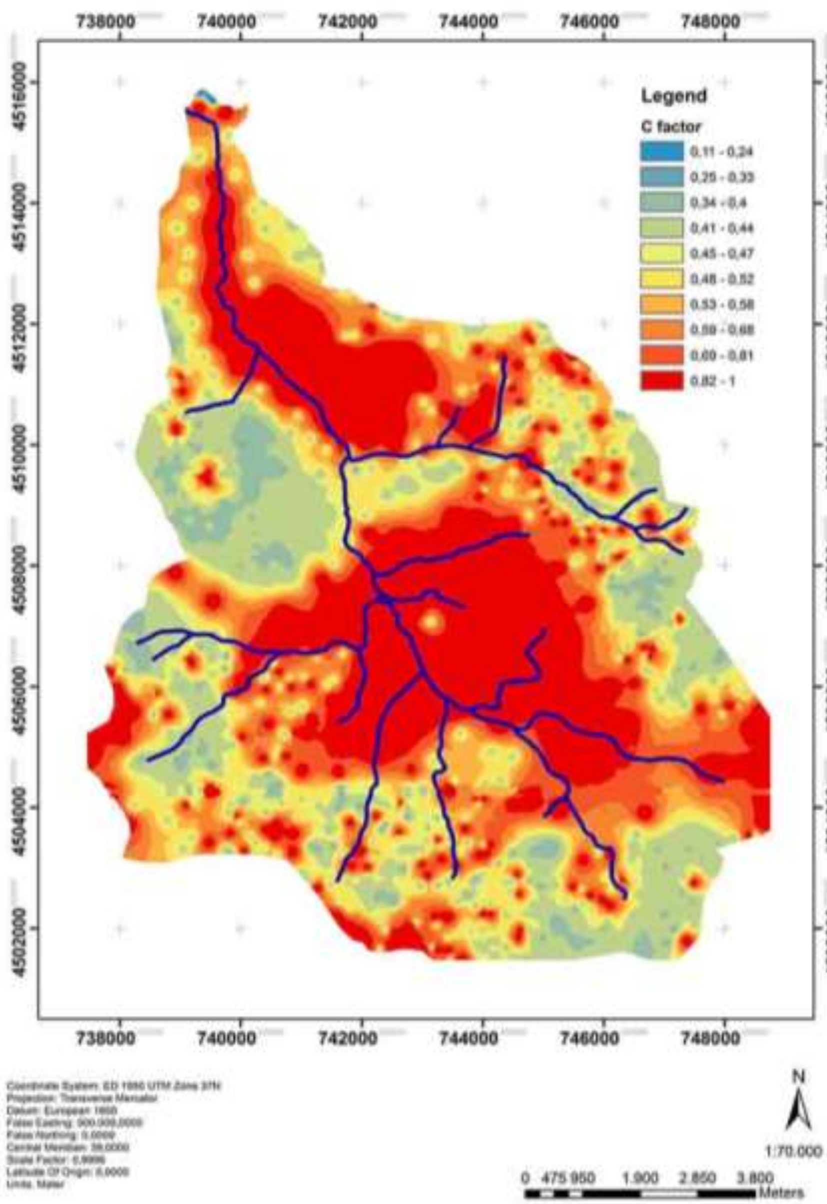

Figure 11. Spatial distribution of “C” factor.

Table 6. Spatial distribution of factor C values of research area.

Factor C values	Spatial distribution	Rate %
0-0.2	2.29	0.02
0.2-0.4	504.86	5.04
0.4-0.6	5869.70	58.60
0.6-0.8	1800.66	17.98
0.8-1	1839.70	18.37
Total	10017.21	100.00

Table 7. Spatial distribution of soil losses.

Soil Loss in current and potential situation	Erosion severity				
	1	2	3	4	5
	0-3 (ton ha^{-1}year^{-1})	3-5 (ton ha^{-1}year^{-1})	5-10 (ton ha^{-1}year^{-1})	10-20 (ton ha^{-1}year^{-1})	> 20 (ton ha^{-1}year^{-1})
	Slight severe erosion	Moderate severe erosion	Severe erosion	Very severe erosion	Extremely severe erosion
Actual situation (ha)	3395.30	442.76	926.83	2036.93	3215.39
% Rate	**33.89**	**4.42**	**9.25**	**20.33**	**32.10**
If damaged forest areas could be rehabilitated (ha)	5048.41	1735.56	893.40	1022.99	1316.85
% Rate	**50.40**	**17.33**	**8.92**	**10.21**	**13.15**
If no precaution is taken (ha)	3181.51	0.00	0.00	0.34	6835.36
% Rate	**31.76**	**0.00**	**0.00**	**0.00**	**68.24**

Figure 12. Views of the barriers in the valley built by DSİ.

Table 8. Average soil loss amounts.

Soil loss in current and potential situations	Average soil loss Ton^{-1}ha^{-1}yıl^{-1}
Actual situation	24.45
If damaged forest areas could be rehabilitated	7.33
If no precaution is taken	58.64

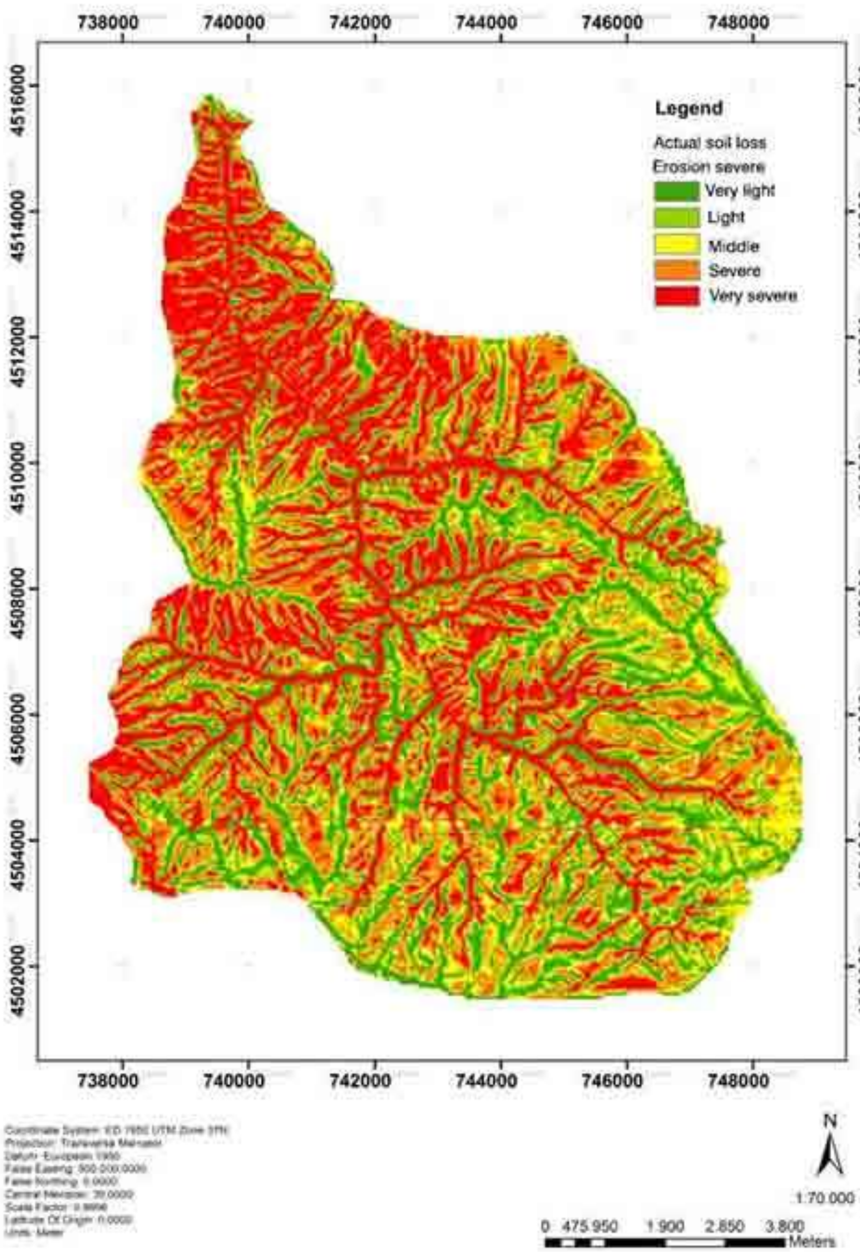

Figure 13. Map of the soil loss.

Figure 14. Erosion images of research area.

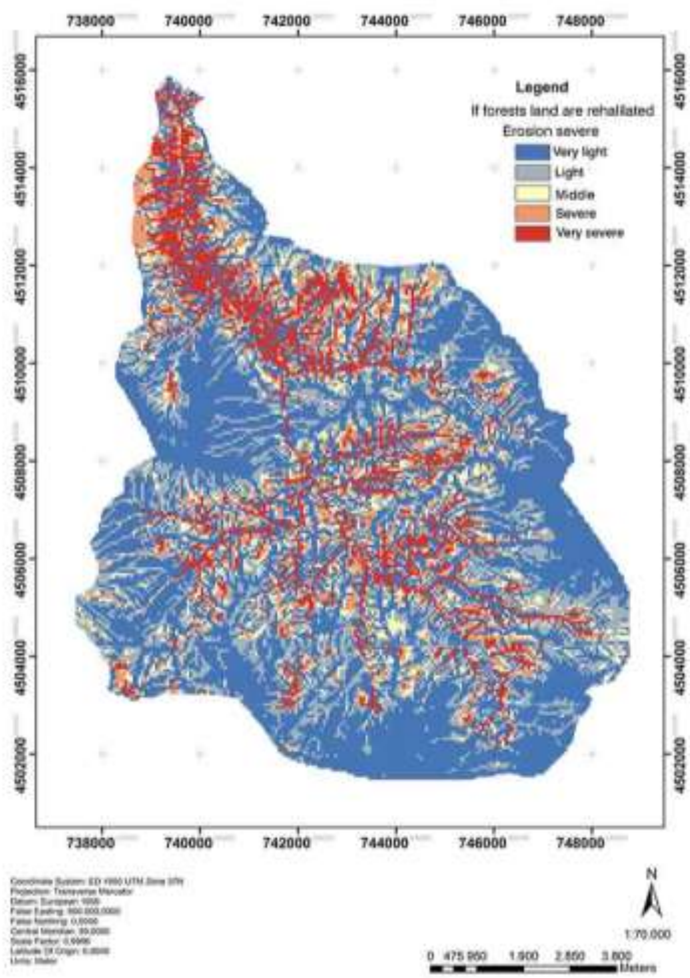

Figure 15. Estimated soil loss map of forest areas after rehabilitation.

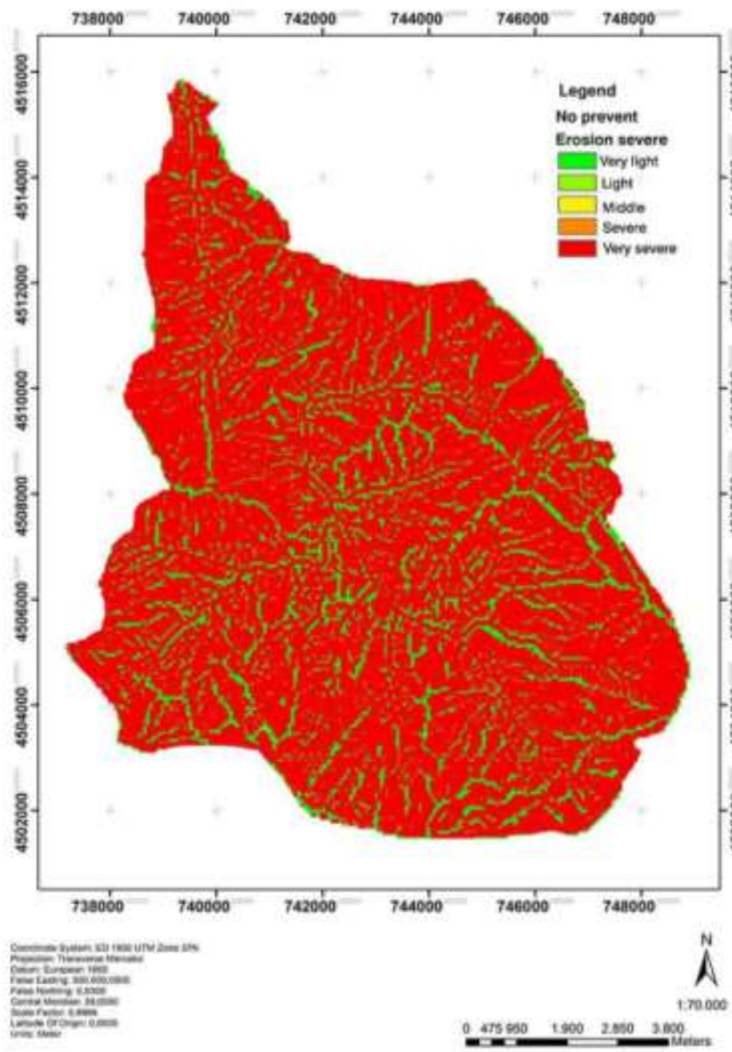

Figure 16. Estimated soil loss map that may occur in case of no precautions.

Conclusions

In order to determine the amount of soil loss and its spatial distribution in the Oltu Anzav Basin, the Revised Universal Soil Loss Equation (RUSLE) method, which is one of the most used methods, was used.

When the results of potential erosion maps generated by the RUSLE method were evaluated, the current soil losses at the basin are estimated as 24.45 ton $ha^{-1}year^{-1}$. If the degraded forest areas could be rehabilitated (afforestation), the potential amount of annual soil loss may be 7.33 ton ha^{-1}. However, if erosion control measures can be implemented in this area, this value could be lowered. If no precautions are taken and the existing degraded forest areas become completely bare under overgrazing pressure, the potential annual amount of soil loss could increase from 24.45 to 58.64 ton ha^{-1}.

For this reason, taking soil conservation measures has become a basic condition for sustainability of the soil. The damaged forest areas belonging to the General Directorate of Forestry should be rehabilitated urgently and also afforestation work should be done. If there is no social problem for the local people, afforestation studies can be practiced within the scope of rehabilitation, and as such rosehip (*Rosa canina*), almond (*Amygdalus communis* L), walnut (*Juglans regia* sp.), yellow pine (*Pinus sylvestris*), and juniper (*Juniperus* sp.) seedlings can be planted in forest areas. Flooding terraces, contour stone bunds, stone threshold and cage wire threshold should be made in slopes of the study basin and then used to prevent floods and erosion at the same time.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Atala I (2008). Ecosystem ecology and geography. Volume: 1. İzmir: META. Printing Services.

Aydin M (2009). Determination of soil losses by WEPP (Water Erosion Prediction Project) according to Land use in the Gumushane-Torul dam watershed. Kastamonu Uni., Journal of Forestry Faculty 9(1):54.

Balci AN (1996). Soil Conservation. Istanbul University Publication No. 3947, Faculty of Forestry Publication No. 439, Istanbul-Turkey.

Bouaziz M, Leidig M, Gloaguen R (2011). Optimal parameter selection for qualitative regional erosion risk monitoring: A remote sensing study of SE Ethiopia, Geoscience Frontiers 2(2):237.

Bouyoucos GI (1962). Hydrometer method improved for making particle size analysis of soils. Agronomy Journal 54:464-465.

Canga M (1995). Soil Erosion. http://www.agri.ankara.edu.tr/soil_sciences/1235_ Bolum_5_Toprak_Kayiplarinin_Tahmini. pdf (Access date: 16.01.2017).

Celik V (2011). Risk analysis of soil erosion in Degirmen Dere Watershed (Bolvadin-Afyonkarahisar). Afyon Kocatepe University, Social Sciences Institute, Geograpy Department graduate thesis.

CEM (2016). Characteristics of rainfall of Turkey RUSLE "R" Factor, General Directorate of Combating Desertification Publications(CEM) 43 p.

CEMGM (A legal department related of Forestry) (2018). Combating Desertification and Erosion General Directorete of Turkey. http://www.cem.gov.tr/erozyon/AnaSayfa/Erozyonyeni/Genel_Bilgi/erozyonn.aspx?sflang=tr Accessed date: 12.09.2018

Ekinci D (2007). Estimating of Soil Erosion in Lake Durusu Basin Using Revised USLE 3D with GIS, Çantay Press.

Irvem A, Tulucu K (2004). Modelling for Estimation of Soil Loss and Sediment Yield Using Geographic Information System (EST) and Application to Seyhan-Korkun Sub watershed. Cukurova University, Cukurova University Science Institute Journal 13:1-7.

Karabulut M, Kucukonder M (2008). Determination of Erosive areas by using GIS in Kahramanmaraş plain and vicinity, KSU Journal of Science and Engineering 11(2):14.

Karaoglu M (2012). Evaluation soil in terms of erosion in Igdır. Igdır University Journal of Science Institute 2(1):23.

Karakas E (2005). Sustainable Management of Küçükelmalı and Güvenç Basins by Water and Sediment Yields. Unpublished PhD Thesis. Ankara University Institute of Science and Technology.

Kumar S, Kushwaha SPS (2013). Modelling soil erosion risk based on RUSLE-3D using GIS in a Shivalik sub-watershed. Journal of Earth System Science 122(2):389-398.

Meghraoui M, Habi M, Morsli B, Regagba M, Seladji A (2017). Mapping of soil erodibility and assessment of soil losses using the RUSLE model in the Sebaa Chioukh Mountains (northwest of Algeria). Journal of Water and Land Development (34):205-213. DOI: 10.1515/jwld-2017-0055.

Meteorological General Directorate (MGD) (2018). Meteorological General Directorate. https://www.mgm.gov.tr/ Access date 17.09.2018

Molla T, Sisheber B (2016). Estimating Soil Erosion Risk and Evaluating Erosion Control Measures for Soil Conservation Planning at Koga Watershed, Highlands of Ethiopia. Solid Earth Discuss. doi:10.5194/se-2016-120, 2016 Manuscript under review for journal Solid Earth, 1

Mineral Research and Exploration (MRE) (2018). General Directorate of Mineral Research and Exploration. http://www.mta.gov.tr/v3.0/sayfalar/hizmetler/doc/TRABZON.pdf Access date: 17.09.2018

Ozdemir AO, Tatar S (2016). GIS- Based RUSLE Method of the Erosion Risk Analysis in Isıklı Lake Basin. Electronic Journal of Map Technologies 8(1):1-21.

Ozsahin E (2014). Evaluation of erosion risk using RUSLE in Tekirdag, 11(3):45.

Ozsahin UE, Keles K (2016). Erosion analysis by RUSLE method in Alakır Watershed (Antalya), Journal of Tekirdag Agricultural Faculty 13(2):123.

Renard KG, Foster GR, Weesies GA, Mccool DK, Yoder DC (1997). Predicting Soil Erosion by Water: a Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). U.S. Department of Agriculture Handbook No: 703, US Department of Agriculture.

Sahu A, Baghel T, Sinha MK, Ahmad I, Verma MK (2017). Soil Erosion Modeling using Rusle and GIS on Dudhawa Catchment. International Journal of Applied Environmental Sciences ISSN 0973-6077 12(6):1147-1158.

Ettazarini S, Jakani ME, Najoui H (2017). Assessment of Soil Loss Risk Using Integrated Remote Sensing and Geographic Information System (gis) Techniques in the Argana Basin, Morocco. American Journal of Innovative Research and Applied Sciences 4(5):186-194.

Sonmez ME, Celik MA, Seven M (2013). Determination of erosion risk areas using GIS and RUSLE in Kilis, Kahramanmaras Sutçu Imam University Journal of Social Sciences 10(1):21.

Tagil S (2007). Evaluation land degradation risk using RUSLE model in Tuzla Watershed, Ecology Journal 17(65):11.

Tufekcioglu M, Yavuz M (2016). Estimating surface soil erosion losses and mapping erosion risk for Yusufeli micro-catchment (Artvin). Artvin Coruh Univ. Journal of Forest Faculty 17(2):188-199 https://doi.org/10.17474/acuofd.47342

Terranova O, Antronico L, Coscarelli R, Iaquinta P (2009). Soil erosion risk scenarios in the Mediterranean environment using RUSLE and GIS: An application model for Calabria (southern Italy). Geomorphology 112(3-4):228-245.

Thomas J, Joseph S, Thrivikramji KP (2017). Assessment of soil erosion in a tropical mountain river basin of the southern Western Ghats, India using RUSLE and GIS, Geoscience Frontiers. http://dx.doi.org/10.1016/j.gsf.2017.05.011

Uzunsoy O, Gorcelioglu E (1985). Basic principles and practices of watershed improvement. Publication of Istanbul University Forestry Faculty.

Williams JR, Berndt HD (1972). Sediment yield computed with universal equation. Journal of Hydraulic Division. Proceedings of the American Society of Civil Engineers 98:2087-2098.

Wischmeier WH, Johnson CB, Cross BW (1971). A Soil Erodibility Nomograph for Farmland and Construction Sites, Journal of Soil and Water Conservation 26 (5).

Wischmeier WH, Smith DD (1978). Predicting rainfall erosion losses. A Guide to conservation planning. United States Department of Agriculture, Agricultural Research Service (USDA-ARS) Handbook, No.537. USDA, Science and Education Administration 62 p.

Yarbasi N (2016). Geotechnical mapping of Oltu (Erzurum) residential area and its vicinity. Pamukkale University Journal of Engineering Sciences 22(6):538-545.

Yuksel A, Akay AE, Reis M, Gundogan R (2007). Using The WEPP Model To Predict Sediment Yield In A Sample Watershed In Kahramanmaras Region. International Congress on River Basin Management pp. 1-21.

Zengin M, Ozer S, Ozgul M (2009). Determination of erosion degree by GIS in Coruh Watershed (Ispir-Pazaryolu) and solution proposals, Atatürk University Journal of Agriculture Faculty 40(1):9-19.

Vol. 13(44), pp. 2542-2550, 1 November, 2018
DOI: 10.5897/AJAR2018.13525
Article Number: 1776D2559124
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Farmers' perceptions, practices and proposals for improving agricultural productivity in South Sudan

Asad Sarwar Qureshi[1*], Adam Juma Abdallah[2] and Lona Aggrey Tombe[2]

[1]Irrigation and Water Management, International Center for Biosaline Agriculture, Dubai, UAE.
[2]Directorate of Agriculture and Rural Development, Juba, South Sudan.

Received 5 September, 2018; Accepted 16 October, 2018

This study was carried out to establish farmers' perceptions regarding low agricultural productivity and to document their ideas for improving the performance of agriculture sector in South Sudan. The results reveal that the major challenges related to low agricultural productivity as perceived by farmers include poor leveling of fields, poor irrigation management, low water availability, loss of land due to salinity and low water use efficiency due to seepage and runoff losses. Low water availability is considered as the biggest challenge for improving agricultural productivity because dependence on seasonal rain results in low crop yields and serious food shortages during most part of a year. Therefore, installation of public wells to increase groundwater availability for irrigation and establishment of rainwater harvesting structures are proposed as the potential solutions to solve irrigation water problems and overcome food shortages. Strengthening of extension services and training of vegetable growers on drip and sprinkler irrigation system along with the provision of irrigation equipment can help a great deal in increasing agricultural productivity. The state and national governments should provide high quality seeds and loans to the vegetable growers to enable them improve their crop production and cultivation of crops during the dry periods.

Key words: Agricultural productivity, irrigation management, food security, livelihood, poverty.

INTRODUCTION

In South Sudan, agriculture account for 36% of the non-oil GDP with 80% of the population living in rural areas largely dependent on subsistence farming (FAO, 2015). Despite abundant water supplies, only 5% of the total 30 million ha arable land is cultivated. Crop yields are extremely low, which negatively affects incomes and livelihood of poor farmers. Lack of agricultural inputs such as seed and fertilizer, poor advisory services and inefficient irrigation management are considered as the major barriers (USAID, 2012). The salt-affected lands in South Sudan are in the White Nile irrigation schemes. The agricultural potential of these areas has hardly been utilized despite having fresh water availability from the Nile River.

About 95% of the land in South Sudan is suitable for agriculture, out of which about 50% is prime land with

*Corresponding author. E-mail: a.qureshi@biosaline.org.ae

high production potential (FAO, 2015). South-Sudan has highest per capita livestock holding in Africa, with 23 million herd of cattle, sheep, and goats. Livestock sector accounts for 15% of the total GDP. Therefore, to improve livestock productivity, there is a strong need for improved forage varieties that are resistant to common diseases (AfDB, 2013). Although agricultural lands in South Sudan are suitable for growing all sorts of crops, land productivity is generally low due to lack of agricultural inputs such as seeds, fertilizer, pesticides, agricultural machinery and higher labor costs (Tully et al., 2015). Farmers in South Sudan rely on traditional methods for seed and grain storage, which increases post-harvest losses as well as nutritional value of the produce (IFPRI, 2012). Availability of labor at reasonable costs and the time when it is most needed is another major issue limiting the crop production (Hanjra et al., 2009). There are critical environmental concerns in South Sudan related to water resources and their management. Water levels in rivers are decreasing due to increased erosion and siltation caused by land use changes and over-exploitation: forest clearing, over-grazing and fires (USAID, 2012).

Irrigation applications by farmers in South Sudan are not related to actual crop water requirements. Most of the farmers do not have access to modern irrigation technologies and irrigation is mainly done using traditional basin or flooding methods resulting in irrigation application efficiencies of 30 to 35% (Kadigi et al., 2012; GoSS, 2013). The studies done in South-Sudan have shown that there is a great potential to boost agricultural productivity if suitable irrigation infrastructure is provided (GoSS, 2013). Poor irrigation and agronomic practices, lack of inputs such as seed and fertilizer, and irrigation and farm machinery are generally considered as the major reasons for low agricultural productivity in South Sudan (World Bank, 2013).

Increasing agricultural productivity at the farm level depends on the farmer's knowledge of the causes of low crop production and the farming practices they should use to overcome this problem. Understanding farmers' perceptions and adaptive strategies to cope with low productivity problems could help in suggesting interventions to tackle this problem (Wickham et al., 2006). Farmers' response strategies are usually based on the timing and severity of the problem perceived and their ability to interpret available information to develop the right response for a given situation (Meze-Hausken, 2000; Kassa et al., 2013). Based on the available information, farmers might decide to employ local mitigation and adaptation practices such as improved land and water management practices, diversify cropping patterns and change their investment decisions (Mamba et al., 2015).

This study was conducted to understand farmers' responses regarding low crop yields and water use efficiencies at their farms. Farmers were asked to describe major constraints faced by them in improving overall agricultural productivity. An analysis of farmers' suggestions for improving the performance of agriculture sector and reducing household poverty in South Sudan was also part of this study. It is anticipated that findings of this study will be used as an entry point for policy makers and other stakeholders to devise effective strategies to enhance agricultural productivity and improve food security and livelihood of millions of poor living in rural areas.

DESCRIPTION OF THE STUDY AREAS

South Sudan is in East Africa bordering Sudan frontier with Ethiopia, Kenya and Uganda; and to the water divide which represents the southern boundary with Democratic Republic of Congo and Central African Republic in the west (Figure 1). The water resources of South Sudan consists of the Nile River, its tributaries, and groundwater. The Blue Nile and its tributaries flow down from the highlands of Ethiopia, while the White Nile and its tributaries flows from Uganda and Central African Republic into the largest contiguous swamp on their way to Sudan and Egypt (The Sudd Region). The low lands of White Nile Valley have great potential for irrigation due to fresh water availability from the Nile River but hardly been utilized for agricultural production (FAO, 2015).

South Sudan has a tropical climate with wet and dry seasons. The temperature typically ranges between 25 and 35°C. During the dry months (January to April), annual temperatures are in the range of 20-25°C, while the highest temperatures can go up to 35°C just before the rainy season (May to September). The annual rainfall pattern is zone dependent ranging from 500 to 2000 mm, which provides 130 to 300 days of growing season. The average annual precipitation in the western parts of the country is between 1000 and 2000 mm, while north-eastern and south-eastern parts of the country receive 500 to 750 mm. Considering these variations, 5 districts from different states of the country were selected to conduct socio-economic survey to establish farmers' perceptions. The selected districts include Aweil, Bentiu, Bor, Torit and Juba districts as shown in Figure 1. The performance of agriculture sector varies in accordance with the zone and the year. The selected areas represent lands with low fertility, poor quality groundwater, and large number of resource poor farmers. The general characteristics of the selected sites are shown in Table 1.

Data collection and analysis

The survey data was collected from a total of 200 respondents from five districts of South Sudan, which were selected using multistage random sampling technique. The selected districts Aweil, Bentiu, Bor, Torit and Juba) have mixed crop-livestock system, therefore, the livelihood of most of the respondents is based on both farming and livestock rearing. In addition to survey data, data from secondary sources regarding groundwater quality and levels, soil maps and information on the status of irrigation water availability and its quality was also collected. Secondary data is essential to get baseline information of the selected areas.

Data were collected using a semi-structured questionnaire, which was developed in consultation with irrigation and agriculture experts of the targeted districts. This strategy was considered better to understand farmers' insights about the causes of low agricultural productivity and document their propositions for improving the performance of irrigated agriculture in the country. The questionnaire was pre-tested in the field by trained enumerators

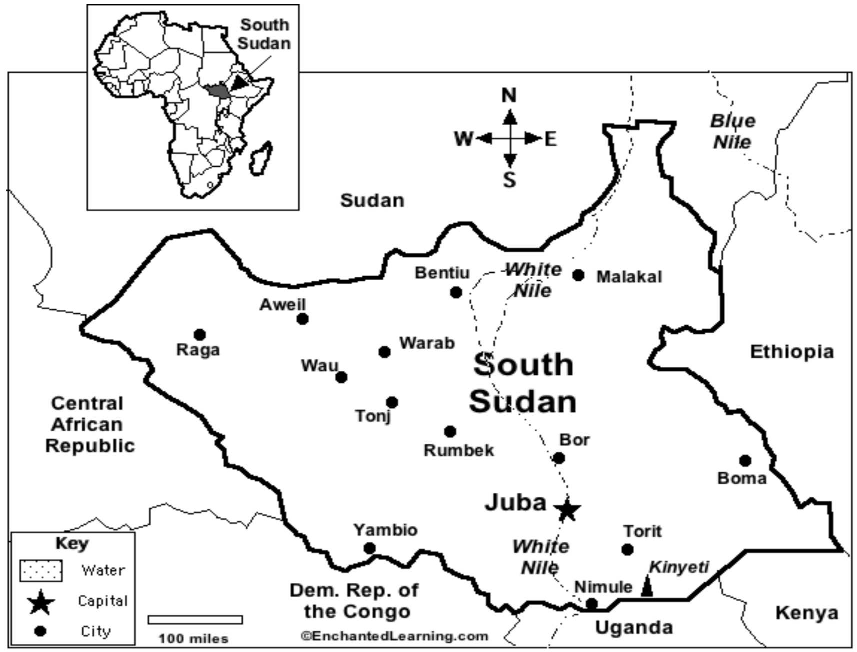

Figure 1. Location of South Sudan**.**

Table 1. General characterization of selected sites in South Sudan.

S/N	Site	Zone	Type of Crops
1	Aweil	Western Flood Plains	Agro-pastoralism: Livestock and agriculture predominant. Main crops are sorghum, pearl millet, vegetables, cow peas
2	Bentiu	Nile-Sobat Rivers	Agro-pastoralism and fishing: Prone to seasonal flooding. Major crops sorghum, beans and vegetables.
3	Bor	Nile-Sobat Rivers	Agro-pastoralism and fishing: Prone to seasonal flooding. Major crops include sorghum, beans and vegetables.
4	Torit	Hills and Mountains	Agriculture and livestock husbandry. Crops include cassava, sweet potatoes, sorghum, maize, finger, pearl millet.
5	Juba	Hills and Mountains	Agriculture and livestock husbandry. Crops include cassava, sweet potatoes, sorghum, maize, finger, pearl millet.

and necessary corrections were made based on the obtained feedback. Focus Group Discussions were also conducted with farmers in each district to record their collective views on the reasons of low agricultural productivity, its impacts on their well-being and their suggestions for improvement.

The selected districts have mixed crop-livestock system; therefore, the livelihood of most of the respondents is based on both farming and livestock rearing. During the survey, farmers were asked about the limitations and constraints faced by them in the adoption of innovative technologies and approaches for improving agricultural productivity. The data collected through household survey, interviews and focus group discussions was used to perform descriptive and econometric analyses using mean, percentage, frequency and analysis of variance (ANOVA). SPSS Version 20 software was used to carry out statistical analysis. The Chi square test was conducted to verify the

Table 2. Demographic characteristics of selected sites.

Parameter	No. of respondents	%
Age range (years)		
20- 30	55	27.5
31- 40	65	32.5
41- 60	76	38.0
>61	4	2.0
Marital status of respondents		
Single	37	18.5
Married	110	55.0
Widowed/Divorced	53	26.5
Education level of respondents		
No Education	47	23.5
Primary education	56	28.0
SSC education	103	51.5
Employment status of respondents		
Unemployed	90	45.0
Private employment	80	40.0
Public employment	30	15.0

significance level of association between farmer's perceptions and their determinants.

RESULTS AND DISCUSSION

Socio-economic characterization of the respondents

The demographic and socio-economic characteristics of respondents include gender, family size, marital status, education level, landholding and livestock ownership. Table 2 shows that 80% of the respondents aged between 20 and 50 years whereas the age of the remaining 20% respondents was above 50 years. This shows that majority of the respondents in this survey were active farmers and represents a good mixture of experienced and young emerging farmers. Out of the total sample of 200 respondents, 135 (67.5%) were male and 65 (32.5%) were female. This disproportion was due to the fact that the male respondents were readily and easily accessible whereas access to female respondents was limited due to their busy schedules at home. The survey results indicate that 55% respondents were married and they practice irrigated farming to earn food and other necessities of life such as health and education for their families and children. Single emerging young and widowed/divorced farmers are mainly involved in subsistence farming. The challenges of food security and livelihood are more significant in divorced/widows.

The education level of respondents was high as about 50% have high school education followed by 27% with primary educated and 23.5% with no formal education. The unemployment rate in the selected areas was very high; 45% of the respondents are without jobs, about 40% rely on part time jobs with private companies and only 15% have secured public sector jobs. The earnings of these farmers are far below their daily needs, which force them to look for additional income generation activities. The low income and higher unemployment rate are reported as the major causes of poverty in these areas.

The *t-test* analysis showed that there is a significant difference ($P < 0.01$) in farm size among households. The average landholding per household was 1.8 ha with a standard deviation (SD) of 0.8 ha. The number of land parcels per household differ significantly ($P < 0.1$) between respondents with a combined mean of 1.25 and a standard deviation of 1.2.

The livestock ownership is considered a proxy for wealth in rural areas of South Sudan. In the survey areas, livestock is a major source of food, income and security in times of hardship for the communities. In this study, the livestock asset of separate households was estimated by tropical livestock unit (TLU) (Storck et al., 1991). The TLU provides a common unit for comparison because households own different livestock species (cattle, goat, sheep etc.). The average livestock holding per household was found to be 8.5 TLU with SD of 1.8 TLU.

Although agricultural production system of the selected districts is a mixed farming system (crops and livestock), farmers prefer to grow crops to secure food supply and satisfy cash needs of their families. The different sources of income reported by the respondents include livestock

Table 3. Types of irrigation and pumping methods used by farmers.

Types of irrigation	No. of respondents	%
Irrigation methods		
Surface irrigation	146	73
Drip irrigation	18	9
Sprinkler irrigation	0	0
None	36	18
Pumping methods		
Lift pump	174	87
Flow pump	26	13
Access to irrigation equipment	152	76

herding, crop cultivation, off-farm wage employment, permanent employment and food aid. The survey results indicate that more than 80% farmers earn their living through crop selling and off-farm jobs whereas permanent employment also contribute significantly to the incomes of the respondents.

The survey results indicate that farmers try to reduce production costs and increase farm income by performing most of the farm activities using family labor. Farm labor activities such as land clearing, ploughing and irrigating are mainly performed by men whereas women contribute more in winnowing and harvesting activities. Other activities such as sowing weeding, bagging, and transporting are largely shared among male and female members of the household.

Household poverty is very pervasive in the selected areas because low crop productivity has direct impact on the income and livelihood of households. The household income of more than 60% of the respondents is less than one US$ per day. Declining farm incomes has forced households to do extra work to earn cash to meet their daily needs resulting in serious health problems especially for women and children. Farmers occasionally lose their livestock due to drought and diseases. This situation made them entirely dependent on food aid programs of national and international organizations for more than 6 months in a year.

The land fertility status in the five districts differs significantly due to various reasons. The respondents were asked to categorize their lands using three fertility indicators, that is, poor (infertile), average and good (fertile). The consolidated results of the survey revealed that the majority of the lands owned by respondents are poor in fertility. About 43% of the respondents consider their land infertile, 51% rated their land as average and about 6% termed the fertility of their land as good (fertile).

Farmers' perceptions about the importance of irrigation

The land holdings in South Sudan are generally small and not all land is cultivated at the same time due to shortage of water and other agricultural inputs. According to survey results, 70% of the farmers have less than 1 ha of land whereas 16% own less than 3 ha and 14% have more than 4 ha of land. Table 3 shows that 42% farmers cultivate vegetables and 28% legume crops to meet their household needs and to earn small money by selling the excess produce in local markets. Cereals and oil crops are grown by 17.5 and 12.5% farmers, respectively. Other crops are grown in small quantities and include groundnuts, vegetables and cassava (Figure 2).

Farmers" knowledge about irrigation management is very limited and majority of them is totally unaware of salinity problems. They usually relate low crop productivity to water shortage and the attacks of insects and diseases. In general, farmers (87%) are aware of the importance of irrigation for sustainable crop production as the rainfall is neither reliable nor sufficient. More than 85% of the respondents believe that the irrigation systems need further development whereas 15% think that first priority should be given to the rehabilitation of the existing irrigation systems.

The survey results reveal that 73% farmers use surface irrigation methods and 9% have installed drip system, whereas the rest 18% rely on traditional flooding method (Table 3). Farmers consider surface irrigation as an income source because it improves their livelihoods through increased crop yield and cultivation of cash crops such as vegetables and fruits both during rainy and dry seasons for the local markets.

More than 87% of the farmers prefer lift irrigation because it is reliable and easy to pump water from surface canals and groundwater wells. In addition, they are less expensive and have minimum operational and maintenance requirements. Many respondents use mechanical pump engines, hand pumps and water-cans to lift water from river and small dug wells for irrigating their fields.

Table 3 shows that 76% of the surveyed farmers have access to one or more irrigation equipment such as pipes, pumps, diesel generators and watering cans. The remaining 24% of the farmers do not own any of these

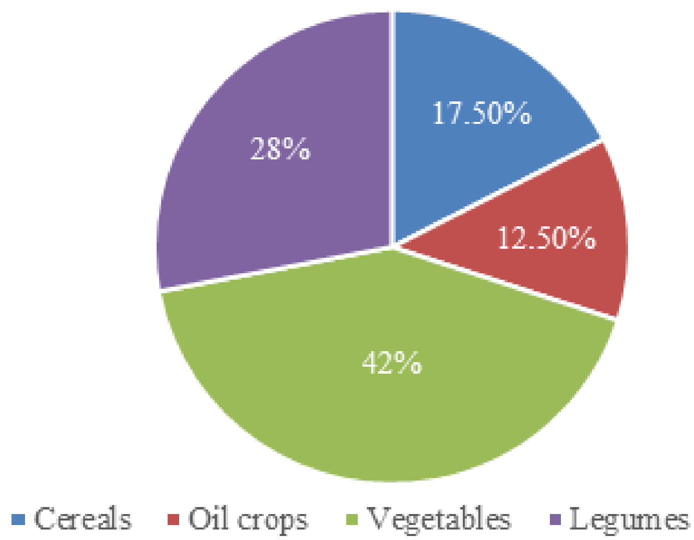

Figure 2. Commonly grown crops in South Sudan.

equipments because of low purchasing power. These farmers either rent or borrow these equipments from their fellow farmers. Most farmers (36%) use 'rotodynamic" type of pumps due to their low cost, high efficiency and ease of installation. However, the drawback of these pumps is that they need skilled labor to ensure regular maintenance and better operation. The poor farmers look to government and donor agencies for financial assistance to buy these pumps.

The farmers were found to have very limited knowledge of crop water demands. In the absence of scientific irrigation scheduling information, farmers' irrigation applications largely depend on the availability of water and visual plant stress indicators. Most of the farmers apply irrigation when the soil surface becomes dry and the crops start showing signs of stress (e.g., dry leaves, changed color of leaves, etc). Resultantly, their irrigation applications are much higher than the actual crop demand. The water applied in excess of crop demand is wasted through surface runoff that damages neighboring fields. During the survey, 80% of the respondents admit that irrigation applications generate surface runoff whereas the remaining 20% do not consider it a big issue. To prevent runoff, farmers use different methods such as land leveling, widening of channels and raising the bunds of their fields.

The survey results indicate that farmers having access to sufficient irrigation water and own pumps tend to apply irrigation twice a day to save their crops from extra water stress. This is an important irrigation practice because discharges are low and temperatures are high, which make the soil dry due to fast depletion of applied water. Farmers having no access to pumps and irrigation water, apply random irrigations depending on the access to water (Figure 3). The results show that 17% farmers irrigate daily, 11% twice a week whereas 19% can only afford irrigation three times a week. These unscheduled irrigation applications produce low water use efficiency and crop yields. This demonstrates that timely access to irrigation water is the biggest constraint in improving agricultural productivity in South Sudan. Mamba et al. (2015) have also stressed the need to match irrigation applications to cover vagaries of climate changes.

Farmers prefer basin method of irrigation because they consider it better to control surface runoff. However, excessive irrigation applications through this method cause depletion of soil nutrients, which exacerbate existing poor soil fertility problems. Farmers complain that they do not get any information from the extension workers or irrigation technicians regarding timing and amount of irrigation water application for different crops.

Farmers' perceptions about the production and market constraints

The information collected from secondary sources revealed that average crop productivities in the selected districts were consistently low. During this survey, farmers were asked about the major production and marketing constraints faced by them for improving their agricultural productivity. The major challenges of irrigation management as perceived by farmers include poor land leveling of fields, lack of irrigation management, less irrigation time, loss of land due to salinity and low water use efficiency due to seepage and runoff losses. More than 95% of the respondents consider lack of agricultural inputs such as improved seed, fertilizer and farm machinery, shortage of arable land, lack of technical knowledge, shortage of irrigation water and increasing

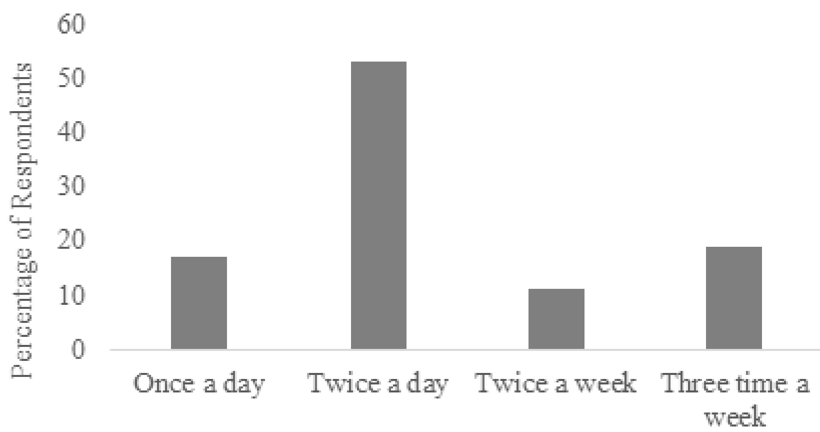

Figure 3. Irrigation schedules adopted by farmers.

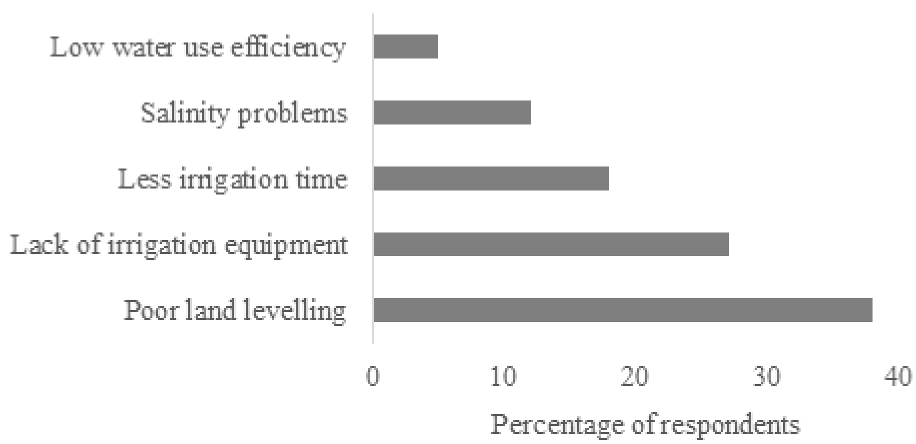

Figure 4. Challenges of irrigation management as perceived by farmers.

salinity as the major constraints for low productivity. In all districts, non-availability of pesticides is resulting in the expansion of invasive weeds.

Figure 4 shows that 38% farmers consider lack of irrigation equipment as the major challenge for improving crop production followed by less irrigation time (27%), low water use efficiency (18%), poor land leveling (12%) and salinity problems (5%). For the leveling of their fields, farmers have to hire the services of companies as they do not have skills and equipment to do it themselves. This makes this task difficult for them. Low water use efficiency is mainly caused by excessive seepage and surface runoff due to the use of flooding method of irrigation. Salinity problems are not widespread in the study areas except in the Bore district.

In South Sudan, farmers hire annual labor for land preparation, planting, weeding and harvesting purposes. The cost of hiring labor ranges from 200 to 1000 South Sudanese Pound (ssp) per day (IUS$ = 130 ssp). Meanwhile, the daily income of the respondents from the sale of their farm products ranges from 1500 to 5000 ssp per day. This shows that farmers earn good income from irrigation farming to cover these costs. However, without irrigation, income levels are low and it becomes hard for them to cover these expenses. Farmers' first preference is to use surface water for irrigation because of its low cost and better quality. However, in the absence of surface water, their ultimate choice is groundwater for irrigation. Some farmers prefer to use groundwater because of its on-farm availability since surface water is far from their farming site.

During the survey, farmers demanded training to increase their level of awareness about irrigation management, crop water requirements and soil management. They suggest that government and/or other concerned agencies should arrange these trainings on regular basis. Farmers think that the government organizations and the NGOs should take appropriate steps for improving irrigation management in South Sudan.

Consistently lower land productivity in the study areas is resulting to reduced farm incomes, food insecurity and sway in poverty. Due to aforementioned constraints, crop yields are generally low and after meeting domestic needs, very little is left for sale in market to earn cash for other family needs. In addition to low produce, farmers are also facing many marketing constraints to get true market value of their produce. During the field survey, lack of market information (42%) and poor infrastructure to access regional markets (32%) were rated as the major marketing constraints by farmers. Farmers also consider involvement of brokers (18%) and high transaction costs (8%) as the main constraint for marketing their products. Due to poor quality of produce and lack of storage facilities, farmers prefer to sell their produce soon after harvesting. The brokers take advantage of the situation and farmers have to compromise on the price.

CONCLUSIONS AND RECOMMENDATIONS FOR IMPROVING AGRICULTURAL PRODUCTIVITY

Results of this study show that household poverty is very pervasive in the selected areas of South Sudan. The land holdings are generally small and not all land is cultivated at the same time due to shortage of water and other agricultural inputs. Farmers were unanimous in declaring low availability of irrigation water as the biggest challenge for improving agricultural productivity in South Sudan. In the absence of irrigation water, farmers depend on seasonal rain, which results in serious food shortages during most part of a year. Therefore, installation of public wells to increase groundwater availability and establishment of rainwater harvesting structures to store rain water needs to be introduced to solve irrigation water problems and overcome food shortages.

Farmers mostly use locally produced seed for growing crops. These seeds are of poor quality and mostly infected which results in low crop productivity. Therefore, farmers should be provided with the quality seed to improve crop yields. Lack of agricultural machinery is also one of the major causes of low crop productivity. Farmers suggest that government should take necessary steps in providing machinery such as tillage equipment, planters, sprayers, levelers, harvesters, threshers and transport trailers to farmers on subsidized rates. Farmers commonly use wide disc planters for land preparation, which uses lots of fuel and damage the soil structure due to excessive moment of tractor and other machinery. The maintenance and availability of spare parts for these machines is a major problem in South Sudan.

The locally produced drip and furrow irrigation systems are useful for smallholder farmers for increasing water use efficiency by minimizing non-beneficial use of water. The benefits of these systems can be maximized if they are properly designed, managed, and maintained. Therefore, farmers should be provided consultancy services to properly design drip irrigation systems. The easy access to manuals and guidelines developed by different manufacturers on different design factors may help farmers improve their skills for properly designing drip irrigation system.

Establishment of agriculture extension services to the farmers should be one of the priorities for the government and stakeholders. Training of vegetable growers on modern irrigation methods such as drip and sprinkler irrigation system as well as provision of irrigation equipment to the farmers can help a great deal in increasing water use efficiency and agricultural productivity. The state and national governments should provide high quality seeds and loans to the vegetable growers to enable them improve their crop production and cultivation of crops during the dry periods.

There is a need to develop a marketing mechanism for buying agricultural products of farmers at their true prices. This will encourage them to increase crop production and improve their incomes. Effective extension program should be initiated to disseminate information on soil, water and salinity management practices to farmers. Farmers should also be linked with national research and extension organizations so that they can benefit from their intervention programs of improving land and water management for increasing their agricultural productivity. Provision of easy credit facilities for farmers might also be a step in the right direction.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors are grateful for the financial support of the International Fund for Agricultural Development (IFAD) for the implementation of this project “Rehabilitation and Management of salt-affected soils to improve agricultural productivity in Ethiopia and South\Sudan”. They are also thankful to the members of the field team in South Sudan for conducting survey and collecting other relevant field data for this study. The help of Dr. Susan Robertson of ICBA in finalizing the questionnaire is also highly appreciated.

REFERENCES

AfDB (2013). South Sudan: An infrastructure action plan. A program for sustained strong economic growth. African Development Bank. Tunis.

Food and Agriculture Organization (FAO) (2013). Sudan productive capacity recovery program (SPCRP). South Sudan. Independent final evaluation. OSRO/SUD/623/MUL. Food and Agriculture Organization of the United Nations (FAO). Rome.

Food and Agriculture Organization (FAO) (2015). South Sudan Country

profile. Geography, Climate and Production. Food and Agriculture Organization of the United Nations (FAO). Rome.
GoSS (2013). The rapid water sector needs assessment and a way forward. Government of the Republic of South Sudan. http://documents.worldbank.org/curated/en/434701468302991568/Main-report
Hanjra MA, Ferede T, Gutta DG (2009). Reducing poverty in Sub-Saharan Africa through investments in water and other priorities. Agricultural Water Management 96:1062-1070.
International Food Policy Research Institute (IFPRI) (2012). Increasing Agricultural Productivity and Enhancing Food Security in Africa. International Food Policy Research Institute, Washington, D.C.
Kadigi RMJ, Tesfay G, Bizoza A, Zinabou G (2012). Irrigation and Water Use Efficiency in Sub-Saharan Africa Briefing Paper Number 4, GDN Agriculture Policy Series. The Global Development Network (GDN), Oxford.
Kassa Y, Beyene F, Haji J, Lejesse B (2013). Farmers perceptions of the impact of land degradation and soil and water conservation measures in west Hareghe zone of Oromia national regional state, Ethiopia. Journal of Biology, Agriculture and Healthcare 3(11):12-19.
Mamba SF, Salam A, Peter G (2015). Farmers' Perception of Climate Change a Case Study in Swaziland. Journal of Food Security 3(2):47-61.
Meze-Hausken E (2000). "Migration caused by climate change: how vulnerable are people in dryland areas? A case study in Northern Ethiopia." Mitigation and Adaptation Strategies for Global Change 5(4):379-406.
Storck H, Bezabih E, Birhanu A, Borowiecki A, Shimeles W (1991). Farming systems and farm management practices of smallholders in the Hararghe Highlands: Farming systems and resources economics in the tropics. Wissenshafts varlag vauk, Kiel, Germany 11:41-48.
Tully K, Sullivan C, Weil R, Sanchez P (2015). The state of soil degradation in Sub-Saharan Africa: Baselines, trajectories, and solutions. Sustainability 7:6523-6552.
United Nations Development Program (UNDP) (2012). Environmental impacts risks and Opportunities Assessment. Natural Resources Management and Climate Change in South Sudan. Government of the Republic of South Sudan and United Nations Development Program.
UN-Water (2015). The United Nations World Water Development Report: Water for a Sustainable World. United Nations Educational Scientific and Cultural Organization (UNESCO), Paris, France.
United States Agency for International Development (USAID) (2012). USAID Country Profile: Property rights and resource governance. South Sudan. United States Agency for International Development. Washington.
Wickham JD, Nash MS, Wade TG, Currey L (2006). Statewide empirical modeling of bacterial contamination of surface waters. American Journal of Water Resources 42:583-591.
World Bank (2013). The rapid water sector needs assessment and a way forward. Republic of South Sudan. World Bank. Washington. https://openknowledge.worldbank.org/handle/10986/2114

Related Journals: