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African Journal of Agricultural Research

Full Length Research Paper

Remote sensing as a complementary tool for monitoring the effects of agricultural policies: The case of the irrigated area of Tadla Azilal (Morocco)

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Agricultural policies are human driving forces that can influence various processes within the landscape due to land-use assignation. Along this work, an innovative methodological framework based on remote sensing techniques is proposed for the analysis of the effects coming from the implementation of any change in agricultural production and for diagnosing the sustainability of irrigated agricultural systems located at arid regions in developing countries. In this sense, the main goal of this paper lies in proposing an efficient and reliable methodology for the multitemporal mapping of cultivated areas at a regional scale and the calculation of socio-economic performance. The undergoing hypothesis is that the emerging "object-based image analysis" techniques could be successfully applied on medium resolution satellite images such as Landsat series. This approach has been tested on a representative region of intensive cultivation in arid areas such as the irrigated area of Tadla Azilal (central Morocco). The application of the developed methodology has allowed helping, as a complementary tool, in strengthening the underlying hypothesis of a relative failure of the liberalization of agricultural production sector and the refunding of the code of agricultural investment after nearly thirty years of its application. In accordance with this hypothesis, yet to be contrasted through other field-based studies, a series of recommendations for improving socio-economic and environmental sustainability of the agricultural system are conducted to serve as guidance for other similar agricultural systems also located in arid areas.

Key words: Object based image analysis, socio-economic impact, remote sensing, developing countries, arid regions, sustainability.

INTRODUCTION

The conservation of agricultural land resources, either in developed or developing countries, is linked to a sustainable and thus profitable agriculture (Ore and Bruins, 2012; Thapa and Gila, 2012). In fact, sustainable agricultural systems must be resource-conserving, environmentally compatible, socially supportive, and commercially competitive (Ikerd, 1990). The challenge for developing countries is to develop land management programs to increase the availability of high-quality fertile lands in areas where population growth is high, poverty is endemic, and existing institutional capacity is weak (World Bank, 2006). Making right decisions largely depends on the quality of the available information. Agricultural policies, through their effect on Land-use, act as strong driving forces that can influence various processes within the landscape and can have an impact on landscape functions (Debolini et al., 2013; Fleskens and Stringer, 2014). In fact, land use, ecosystem service values and local economy have a close relation (Zhang et al., 2013). In this sense, people migrate from degraded to more fertile areas, from the countryside to cities, from regions that cannot provide sufficient resources to sustain people's livelihoods to more fortunate places. This is one of the main drivers of agricultural land abandonment and the subsequent soil degradation of previously very productive irrigated areas in developing countries. As a case study, we have focused our work on the irrigated area of Tadla Azilal, located at central Morocco. This area actually constitutes an oasis within an arid region due to its water availability coming from the Atlas mountain range. However, the problem of shortage of irrigation water in Tadla Azilal began to be especially worrying at early 80's, being aggravated by a succession of droughts from 1981 to 1984. This resulted in the need to use the groundwater as an alternative resort, which entailed more pressure on non-renewable resources.

Regarding the historical trajectory of agriculture in Morocco, "Le Code des Investissements Agricoles" (CIA or Code of Agricultural Investment), enacted in July 1969, can be considered as one of the main legislative instruments and tools headed up to the control and management of agriculture and irrigation water in this country. The aforementioned code is presented as a contract between farmers and the State, defining rights and duties in public Large Scale Irrigation schemes. Historically, this policy has been coined as "*Politique des Barrages*" which consisted of huge investments by the State in public irrigation infrastructure (that is, building of huge dams) with the objective of reaching the milestone of 1 million ha of irrigated agricultural land by 2000 (Diao et al., 2005). In short, the State held the equipment and the management of large irrigated areas in exchange for a financial contribution of the farmers in the form of a tax, which was a function of the volume of water used, to defray operating costs, maintenance and amortization of irrigation infrastructures. In addition, agricultural land-use in these potentially very productive areas has been rigidly regulated by the State during a long time. For example, it was established a rigid crop rotation system that prevented farmers to make their own decisions.

After almost thirty years of application of the aforementioned state wide planning system, Moroccan agricultural sector did not significantly improve mainly due to the heavy and selective intervention of the State to regulate markets and control prices for so-called "strategic" commodities, which translated technically into controlling the flow of imports and exports. The combined effect of these policies has led to an implicit taxation of the sector, especially when accompanied with the overvalued exchange rate at the time (Doukkali, 2006). Consequently, Moroccan Ministry of Agriculture, Rural Development and Fisheries proceeded to the liberalization of agricultural sector.

The production system adopted throughout the kingdom of Morocco, and particularly in the irrigated area of Tadla Azilal, has been traditionally characterized by its majority dedication to the production of cereals, sugar beet and fodder, actually being a continuation of the agricultural system applied during the protectorate. After the liberalization of rotating systems, it is advocated the implementation of a more profitable and sustainable agriculture that can ensure its future continuity by setting population-based and preventing emigration. However, there are not rigorous studies of the region which provide specific information regarding the spatio-temporal distribution of the main crops neither before nor after the process of liberalization.

This paper seeks to contribute a methodological framework at regional scale to help evaluate the effects of agricultural policies in developing and arid/semiarid areas (scarcity of field data and available water). Therefore it is crucial both to count on indices to measure the efficiency of water use and effectively know their spatio-temporal dynamics. In this context both Remote Sensing and the Socio-Economic Productivity (SEP) indicator proposed by García Lorca (2009) could be seen as very useful tools to help decision makers in the analysis of the agricultural system. Taking into account that mapping and monitoring of vegetation species using traditional field-based methods is costly and time-consuming (Mansour et al., 2012), Land-use (LU) monitoring based on Remote Sensing and an Object Based Image Analysis (OBIA) approach has been applied in this work. In fact, there are many works related to remote sensing applications for mapping multi-year cropping patterns from Landsat imagery based on either traditional per-pixel approach (Martínez-Casasnovas et al., 2005; Alexandridis et al., 2008) or OBIA techniques (Vieira et al., 2012).

Regarding OBIA techniques, they rely on aggregating similar pixels to obtain homogenous objects (image segmentation stage), which are then assigned to a target

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Figure 1. Location of the study site (irrigated area of Tadla Azilal, Morocco).

class (classification stage). Using objects instead of pixels as a minimum unit of information minimizes the salt and pepper effect due to the spectral heterogeneity of individual pixels. Unlike traditional pixel-based methods that only use spectral information, object-based approaches can use shape, texture, and context information associated with the objects and thus have the potential to efficiently handle more difficult image analysis tasks (Blaschke, 2010; Marpu et al., 2010), thus improving the performance of supervised classifiers, both for high (Lee and Warner, 2006; Blaschke, 2010; Myint et al., 2011) and low spatial resolution satellite imagery (Flanders et al., 2003; Dingle and King, 2011; Ceccarelli et al., 2013). The application of the proposed approach should allow the detection of potential spatio-temporal changes in cropping patterns over the irrigated area during the period studied and therefore help evaluate, together with complementary and necessary field-based data, the success or failure of the policy measure consisting in the liberalization of Moroccan agricultural production sector and the refunding of the code of agricultural investment after nearly thirty years of its application.

MATERIALS AND METHODS

Study site description

The irrigated area of Tadla Azilal belongs to the region of Tadla Azilal (Figure 1), located at the Southeast area of Morocco, 200 km from the economic capital of Morocco (Casablanca). The region covers an area of 17125 km^2, while the irrigated area under study represents 21% of this area, lying in a plain with an average height of 400 m. Tadla Azilal is divided by the river Oum Er Rbia in two sub-areas: Beni Moussa and Beni Amir. Regarding quality of the irrigation water used in the area of Beni Amir, it comes from the river Oued Oum Er Rbiaa and it is characterized by slight salinity with values ranging from 0.6 to 1.3 g/L (Nemmaoui, 2011). In the case of Beni Moussa, the principal source of irrigation water is the dam of Bin El Ouidan-Oued el Abid, generally contributing good irrigation water quality (Nemmaoui, 2011).

The area occupied by the irrigated area of Tadla Azilal is close to 325095 ha and can be classified as agricultural land, forest and uncultivated areas. Tadla Azilal is subject to environmental constraints such as low and unpredictable seasonal rainfall, high mean annual temperatures and high evaporative demand, which severely limit water supplies for agricultural use. Moreover, existing constraints are likely to be exacerbated by climate change, with temperatures expected to rise and water supplies to become increasingly scarce (Rosenzweig et al., 2004), particularly in Africa (Orindi and Murray, 2005).

Economic benefits of irrigation water

To include sociological factors derived from the use of irrigation water, we adopted the indicator "*Socio-Economic Productivity (SEP) of irrigation water*" proposed by García Lorca (2009), which includes irrigation water consumption, economic performance and potential employment generated, formulated through the next expression:

$$SEP = \frac{[(60 \times SP) + (40 \times EP)]}{100} \quad (1)$$

Where SEP is the socio-economic productivity of irrigation water

Table 1. Description of Landsat imagery used in this work. (*) RMSExy means Planimetric Root Mean Squared Error.

Sensor	Date	Number of bands	Ground Pixel Size (m)	RMSExy(*) (m)
Landsat 1-3 MSS	March 7, 1973	4	60	28.5
Landsat 4	April 5	4	60	30.7
Landsat 7 SLC	February 14	7	30	5.7
Landsat 4	May 16	7	30	3.9
Landsat 7 SLC	May 27	7	30	5.7
Landsat 4	May 30	7	30	4.3
Landsat 4	June 4	7	30	4.1
Landsat 4	June 7	7	30	4.2

(€/m3), EP is the economic productivity (measured as the ratio between the production value and the water consumption) and SP means the social productivity (that is, the ratio between the demanded working days and the water consumption multiplied by the corresponding Day's wage). The assessment of the demanded working days and day's wages for every crop was carried out by using a representative survey over 79 farmers in the area (Nemmaoui, 2011), of which 97% used the traditional method called "Robta" or surface irrigation. 66% of farmers polled worked in Beni Moussa and 34% in Beni Amir.

Satellite imagery for multitemporal crop monitoring

Landsat satellite images, covering the study area distributed by USGS through Global Visualization Viewer (Glovis, 2013), were employed to undertake the multitemporal analysis of the agricultural crops spatial distribution in the irrigated perimeter of Tadla Azilal. Taking into account that the date of acquisition of images is crucial and directly linked to the type of phenomenon to be studied (Doraiswamy et al., 2004), spring-summer season would be usually preferred to acquire Landsat images headed up to inventory and spatially locate irrigated crops over the working area (Table 1). Indeed, in late spring to early summer all target crops are in a suitable growth stage to be detected by remote sensing techniques (Chuvieco, 2008). As can be seen in Table 1, the maximum planimetric error after Landsat images georeferencing was always lower to 0.6 pixels (subpixel error), so it may be considered acceptable to achieve the objectives proposed in this work.

Multiscale object based image analysis

According to the approach proposed in this paper, the application of OBIA classification includes the following steps: i) image segmentation and retrieval of objects, ii) selection of training samples (objects), iii) classification based on supervised features computed for each object in the training sample, iv) where applicable, subsequent edition of the supervised classification. The steps 1º and 3º are executed automatically after choosing appropriate parameters and values, while the steps 2º and 4º are basically manual and fundamental processes, since the final results depend, to a large extent, on the precise selection and review of the samples.

The value of the scale parameter affects image segmentation by determining the size of image objects. If the scale value is high, the variability allowed within each object is high and image objects are relatively large. Conversely, small scale values allow less variability within each segment, creating relatively smaller segments. The point is that all image objects are part of the image object hierarchy, which may consist of many different levels at different scales but always in a hierarchical manner (from coarser to finer scales).

The software used to carry out objects segmentation and classification was eCognition Developer 8.0©. It implements an algorithm called multiresolution segmentation which is a bottom-up segmentation algorithm based on a pairwise region merging technique trying to locally minimize the average heterogeneity of image objects for a given resolution of image objects. The workflow adopted in this paper to apply OBIA techniques on Landsat images started with a coarse segmentation of the scene (scale = 65) using an equal weight to all Landsat bands excluding the thermal layer. The weight of colour (spectral heterogeneity) was set to 0.8 and, therefore, its complementary shape heterogeneity weight equalled 0.2.

This initial segmentation produced super-objects of large scale which were classified in non-vegetated (urban areas, bare earth, roads and channels and water) and vegetated areas (Figure 2) by means of thresholds based on vegetation indices which will be described later. The threshold for each Landsat scene was set by means of a trial and error process according to the visual results. From the initial super-objects classified as vegetated, and applying a top-down segmentation process (scale=10), homogeneous sub-objects of the appropriate size for containing approximately the different types of crops (target classes) were obtained. Working at this sub-object level, a supervised classification based on Nearest Neighbour (NN) classifier was applied to obtain a finer classification from the vegetated macro-level class (Figure 2).

Unfortunately it was not available an adequate *Ground-Truth* to train the classifier and validate the final results, since we are working on Landsat archival images where, for obvious reasons, it is impossible to make the corresponding field work. On the other hand, it was impossible to achieve (maybe even they do not exist) higher resolution images of the irrigated area of Tadla Azilal from satellite or photogrammetric flights that can help the extraction of samples for training or validation. This situation, relatively common in developing countries, forced us to test an alternative and novel approach based on the consultation of yearly official inventories for target crops (indirect and not georeferenced data). The official inventory used in this study was provided by the Office Régional de Mise en Valeur Agricole du Tadla (ORMVAT; personal communication).

In this case, five main types of crops were analysed: cereals, sugar beet, vegetables, fruit trees (mainly citrus fruits and olive groves) and forages. The widely known K-means clustering method (Spath, 1985) was employed to automatically take into account potential divergences between the multidimensional features vector (based on the 14 features described in the next section) and so classify every sub-object belonging to the super-class vegetated in five a priori unknown clusters or classes. In this way, we are given a dataset of N sub-objects in a p-dimensional space (being p = 14 the dimension of the features vector) and an integer of K (in this case K = 5). The problem is to separate the N sub-objects into K clusters

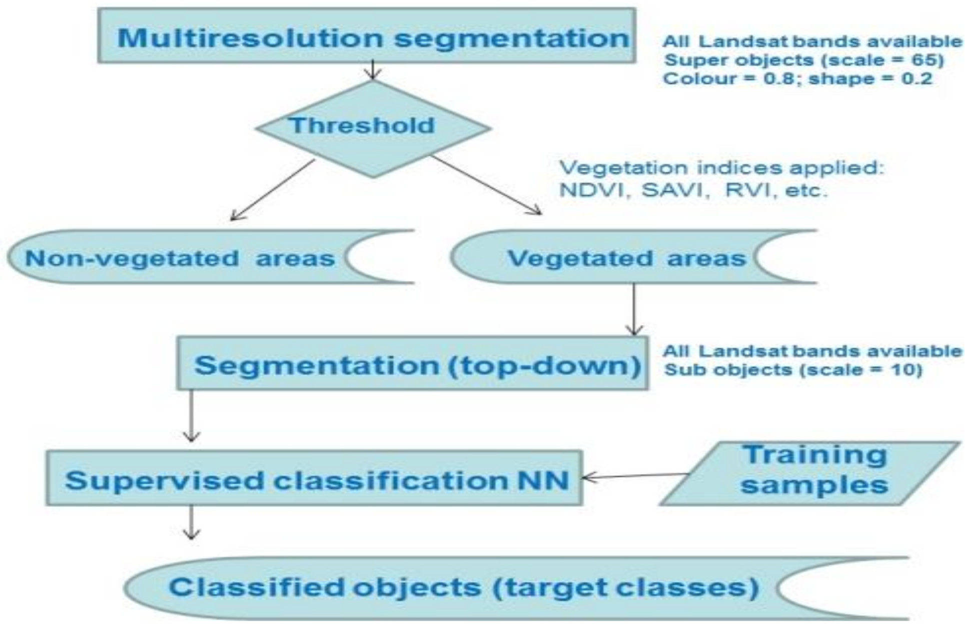

Figure 2. General flow chart of the proposed OBIA based classification algorithm.

by means of an iterative algorithm that minimizes the sum of distances from each sub-object to its cluster centroid over the remaining clusters. This algorithm moves sub-objects between clusters until the sum cannot be decreased any further. Our particular result would be a set of five clusters that are as compact and well-separated as possible and so they should roughly correspond to the five groups of crops we are looking for. Afterwards we can use a certain subset of sub-objects near the corresponding class centroid as training samples for feeding our Nearest Neighbour classifier and compare or validate the classification results against the area assigned to each target crop reported by the official inventory every year. The process turns out to be iterative in the sense that large deviations between classified and official data forces to select a new subset of training samples by simply changing the training samples around every centroid of the initial unsupervised clusters. The iterative process is stopped when computed deviations seem to be reasonably small. After several trials, and in the case of Landsat images and crops analyzed through this work, it is recommended that the number of training samples should be around 25 items for each type of reference (with an average of 200 pixels each one). The flow chart corresponding to the described algorithm is depicted in Figures 2 and 3.

The approach addressed in this section was separately applied to each of the Landsat scenes described in Table 2. The goal consisted of the evaluation of the semi-automatic classification obtained through the use of OBIA techniques to identify signatures based on the multidimensional feature vector explained in the following section for each one of the major crops at the irrigated area of Tadla Azilal. In the case of 1973, we did not have available data of the crop inventory, so it was used the training corresponding to the scene of 1987 (which was taken with the same sensor Landsat MSS).

Description of the features used to carry out crop classification

Selected features have to be suitable to carry out the detection of plant biomass to separate vegetated and non-vegetated areas at largest scale (binary super-object classification by threshold selection at segmentation scale = 65 in Figure 2). For that reason the following widely known vegetation indices were used:

(i) Normalized difference vegetation index (NDVI)

Typical values found for dense vegetation canopy tend to be positive (say 0.3 to 0.8), while bare soil generally tends to generate rather small positive NDVI values ranging from 0 to 0.2. Several studies have shown that accumulated NDVI correlates well with crop production in semiarid areas (Doraiswamy et al., 2004). Furthermore, the absence of blue band in NDVI helps to mitigate atmospheric effects (Ünslan and Boyer, 2004).

$$NDVI = \frac{Nir - R}{Nir + R} \quad (2)$$

(ii) Ratio vegetation index (RVI)

It is sensitive to soil optical properties and less sensitive to light conditions:

$$RVI = \frac{Nir}{R} \quad (3)$$

(iii) Soil adjusted vegetation index (SAVI)

Developed by Huete (1988), it is considered very useful to be applied in semi-arid areas because of it minimizes the disruptive effect of the reflectivity of the soil by introducing the factor L. This factor is an empirical variable coming from the data adjustment to the line of vegetation-soil and ranges from 0 (very high density vegetation) to 1 (low density vegetation). In this sense, the most

Table 2. Estimates of the socio-economic productivity for the crops located at Tadla Azilal by applying equation 1 (compiled by from field survey and data provided by ORMVAT).

Crops	EP (€/m^3)	SP (€/m^3)	SEP (€/ m^3)
Cereals	0.52	0.11	0.27
Sugar beet	0.21	0.09	0.14
Forages	0.16	0.04	0.08
Vegetables	0.82	0.61	0.69
Citrus fruits	0.33	0.08	0.18
Olive grove	0.18	0.15	0.16

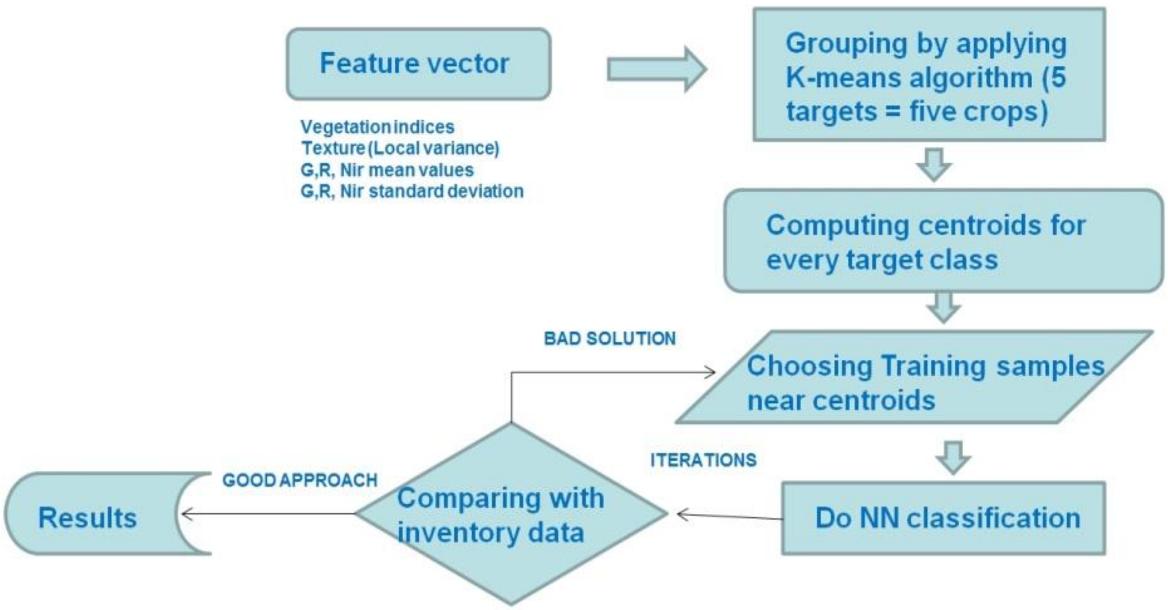

Figure 3. Flow chart corresponding to the proposed training algorithm based on tabular data.

commonly used value is L = 0.5 corresponding to a middle plant cover.

$$SAVI = \frac{Nir - R}{Nir + R + L}(1 + L) \quad (4)$$

(iv) Infrared percentage vegetation index (IPVI)

It was developed by Crippen (1990) from the previously discussed formulation of NDVI, which suggests that the spectral subtraction of the value contained in red band is not relevant. In this case the values are ranged within the interval 0 to 1:

$$IPVI = \frac{Nir}{Nir + R} \quad (5)$$

(v) Difference vegetation index (DVI)

Proposed by Richardson and Everitt (1992):

$$VI = Nir - R \quad (6)$$

Once vegetated areas were identified, a new segmentation-classification process were carried out at a lower segmentation scale (scale = 10) in these vegetated areas as it was described in the last section (Figure 3). Working at the lowest scale segmentation level, sub-objects were classified by applying NN supervised classification from a high-dimensional feature vector constituted of the following features: i) the five vegetation indices previously described, ii) G, R and Nir mean values computed for each sub-object, iii) G, R and Nir standard deviations computed for each sub-object and iv) texture feature based on local variance computed on G, R and Nir bands. Regarding the texture feature estimated from local variance, the approach proposed in Fernández et al. (2013) based on a 3x3 pixels kernel was applied.

RESULTS AND DISCUSSION

Table 2 shows the results coming from the application of the previously described SEP indicator for each crop.

According to these data it is worth noting that vegetables crop presents the highest socioeconomic productivity (0.69 € per m3 of irrigation water consumed), followed by cereals and finding forage crop located at the last place. The same can be said for social productivity, which vegetables crop presenting the highest value and fodder the lowest one. With regards to economic productivity, again vegetables crop reaches the top followed by cereals.

In a context of arid areas where water availability is low, it is crucial to make profitable the agricultural system by increasing production through an efficient and sustainable water use. It can be highlighted that, according to the "Regional Office of Agricultural Development of Tadla Azilal" data (ORMVAT; personal communication), averaged over the 10 seasons ranging from 1994 to 2005, forage crops have been those that presented the largest water consumption, reaching a percentage of 34.4%, although this crop only covers around 18.6% of the irrigated area. Then there are citrus and sugar beet, both together representing 27.8% of total water consumption and covering almost the same area as fodder. Cereals demand less water per hectare although cover an area close to 39.5% of the total irrigated area. Thus they consume around 18.2% of total irrigation water consumption. Moreover, the dominant crops in the perimeter of Tadla Azilal (wheat, sugar beet and fodder) have an annual net profit which fluctuate between 900 and 1700 €, while the net margin of horticultural crops reaches values around 2500 €.

Regarding results coming from the proposed object-based remote sensing approach, in Figures 4 and 5 are shown with two graphical examples of the classification results obtained for multitemporal monitoring of the main crops cultivated in the irrigated area of Tadla Azilal (classifications corresponding to 1973 and 2010 Landsat data respectively). The comparison between the percentage of area covered by each crop with respect to the total area regarding the values estimated by OBIA techniques and data registered in the Official Agricultural Inventories of ORMVAT (Table 3) indicates an acceptable estimation coming from OBIA approach, yielding a mean deviation value of -11.08% (general underestimation of cultivated land) and a standard deviation or uncertainty close to 14.75%. The average for absolute deviations took a value of 13.53%. In this regard, the deviation values were found quite similar for all target crops except in the case of vegetables, where OBIA techniques tended to underestimate the true values, especially during the years 1987 and 2001. This was mainly due to the month when Landsat images were taken in 1987 and 2001, that is April and February respectively. Indeed, the vast majority of crops in the area are usually sown in March and proper crop remote detection would only be effective when plant presents an advanced phenological stage, which would be set up from May to June for Tadla Azilal region. It is important to underline that Landsat sensor data from one or two dates (typically winter and summer) have been used for classification in previous mapping studies such as LCM2000 (Fuller et al., 2002). The idea is to enhance the contrast in the spectral reflectance associated to different phenological stages. However, optical imagery from more than two dates within an annual cycle have rarely been used for classification due to the prevalence of cloud cover in winter and the logical requirement for multitemporal observations, which makes this alternative more cumbersome and costly (Lucas et al., 2007). Furthermore, and for the study area of Tadla Azilal, earlier or later June-July Landsat scenes would likely produce a more variable reflectance of vegetation because of leaf production and senescence usually occurs outside this time interval. Thus, it is strongly recommended using scenes taken within May to July season in order to optimize the overall classification results at Tadla Azilal irrigated area.

Attending to the spatial distribution of major crops, one of the main advantages of the proposed approach, it can be noticed the presence of specialized clusters. For example, the area of Beni Amir is specialized in growing cereals and fodder, while sugar beet is mainly grown in the area of Beni Moussa and especially in the eastern zone. Vegetable crops, the more profitable from the standpoint of efficiency in water use, do not exceed 8% of the total cultivated area, being situated mostly in the sub-perimeter of Beni Moussa where a higher quality of irrigation water from the dam of Bin El Ouidan-Oued el Abid is available.

Regarding fruit crops, and as it was already defined during the protectorate period, they are mainly distributed in the area of Beni Moussa. Again the difference in quality of irrigation water may explain this spatial distribution and, thus, fruit crops are the only crops that seem to keep their traditional cultivated area. In both sub-areas can be highlighted the strategic situation of almost all farms devoted to fruit production, always close to main roads of the zone. Another important characteristic refers to the large fluctuations in the location and size of these fruit farms, and its evolution over the analyzed period.

This is due to the fact that fruit farmers are used to intercalate forage crops between fruit trees to increase their benefits. That intercropping application has led to some problems for remote sensing classification of the class fruit crop. In this regard, and to avoid confusion, it was decided to classify these mixed crops according to the majority crops around them (contextual classification) and/or the apparently dominant crop (forage or fruit), although this actually implies some loss of fruit covered area which, in principle, is not significant for the purposes of our study.

It is worth noting that the main crop of the area, according to covered area over the total, turned out to be cereals (Figure 6), with an efficiency in water use,

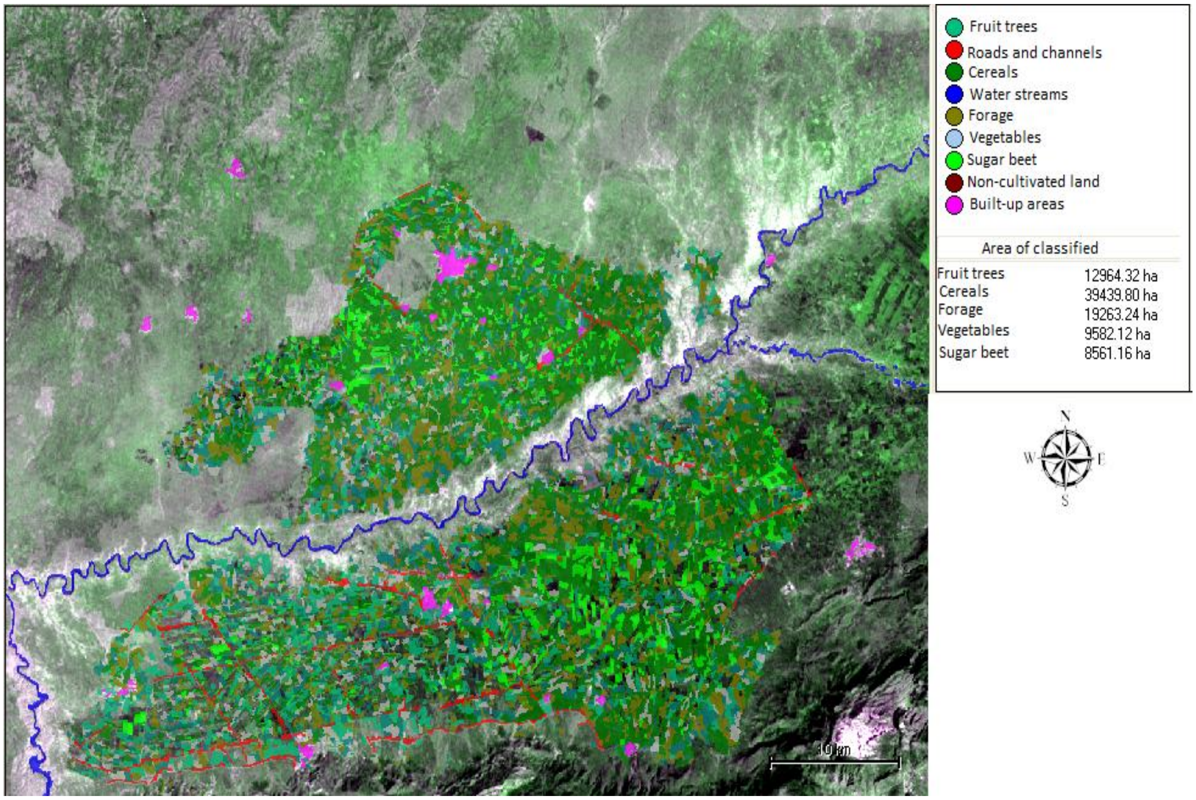

Figure 4. Results from OBIA classification corresponding to 1973. Landsat MSS imagery.

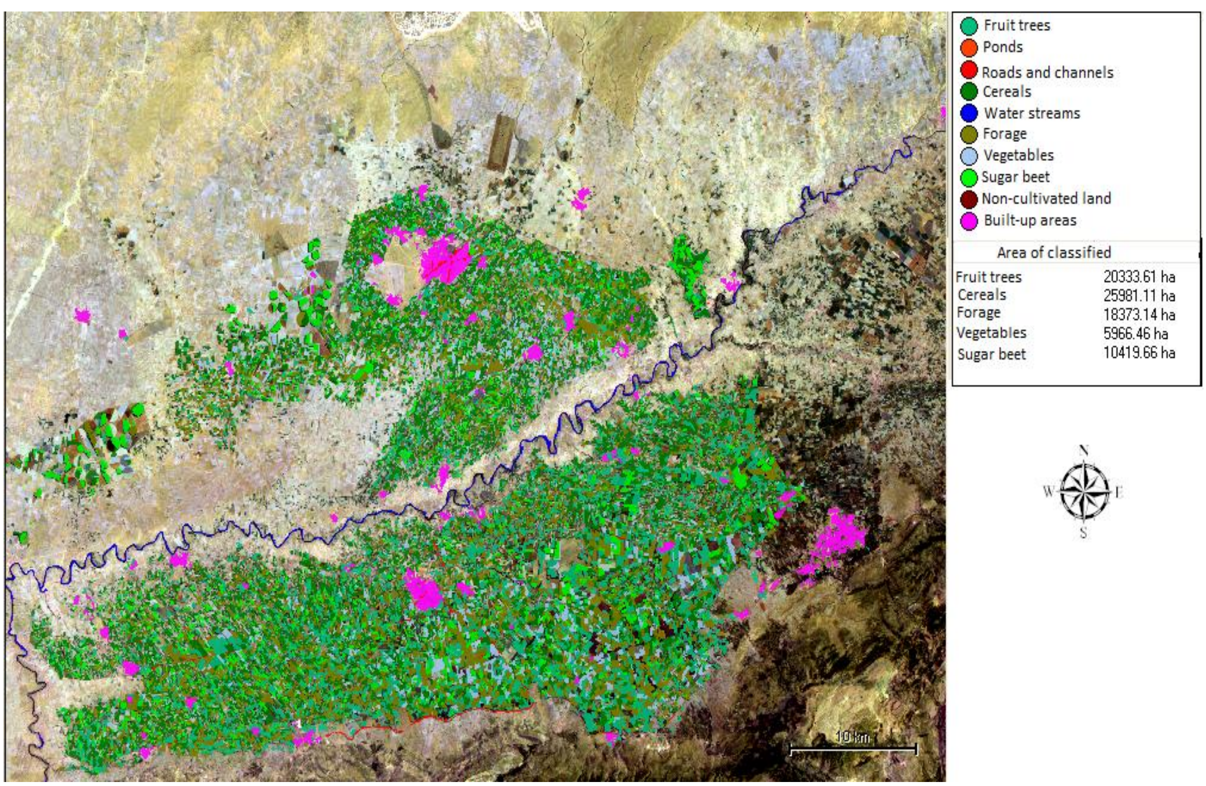

Figure 5. Results from OBIA classification corresponding to 2010. Landsat TM imagery.

Table 3. Deviations between the results estimated from the proposed OBIA method as compared to data from ORMVAT official inventory regarding the area covered by each crop with respect to the total area (100(OBIA-inventory data)/inventory data). No inventory data were available for year 1973.

Crop	Season						
	1987 MSS	2001 ETM	2002 TM	2003 ETM	2007 TM	2009 TM	2010 TM
Cereals	-14.68%	-13.34%	2.76%	-20.55%	-12.90%	-14.94%	-25.76%
Sugar beet	-6.05%	-5.79%	0.82%	-11.01%	1.01%	-24.61%	-6.13%
Vegetables	-44.80%	-56.21%	-7.29%	37.03%	-------	-13.97%	-0.56%
Fruit trees	-6.02%	-5.86%	-8.82%	-11.24%	-11.23%	-7.03%	-22.39%
Forages	-16.90%	-6.16%	-10.45%	-6.82%	-1.10%	-5.79%	-19.94%

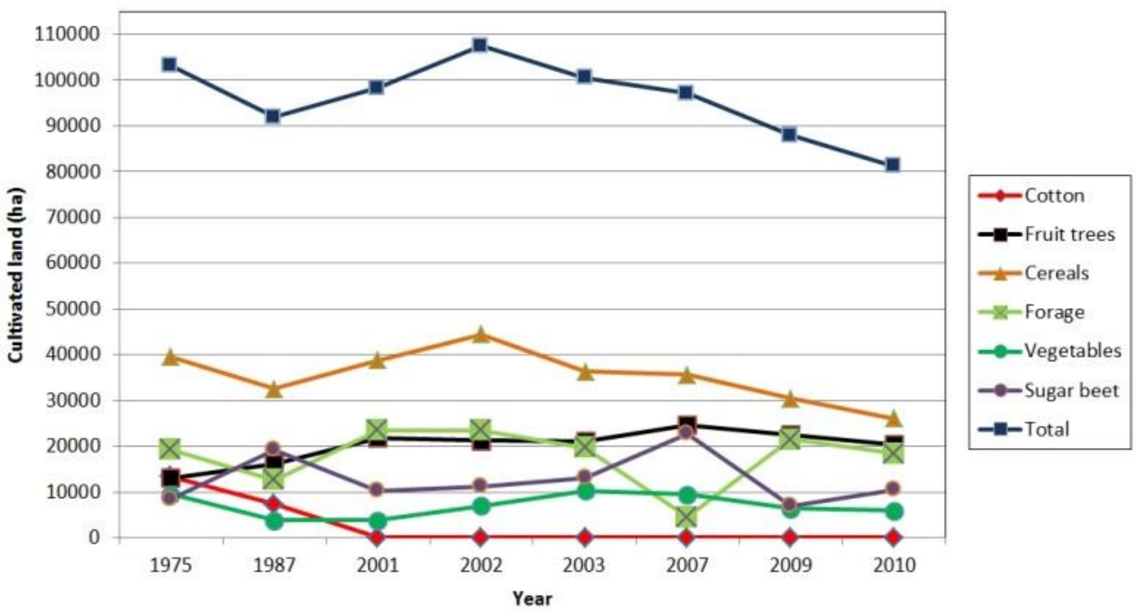

Figure 6. Temporal evolution of cultivated land over Tadla Azila irrigated area.

measured as socio-economic productivity (SEP), of 0.27 € m^{-3}. Vegetable crops, which presented the highest efficiency index (SEP = 0.69 € m^{-3}), only occupied the last position regarding covered area. Also from data shown in Figure 6, it may be noticed a slight decrease of the total cultivated area mainly due to the reduction of cereals and sugar beet. The only crop that has registered an increase over the last three years has been forage what can be attributed to the fact that it is the choice of farmers to cope with drought and especially market fluctuations, as this particular crop ensures a steady income through high demand due to the shortage of pasture.

Finally, it has been checked that vegetable crops offer the greatest efficiency in the use of irrigation water and thus generate larger socioeconomic production, even tripling that of traditional crops. However, vegetable crop is a minority due, among other factors, to the uncertainty related to the policy adopted by the ORMVAT within the framework of the CIA. Indeed, ORMVAT policy in dry years advocates dedicating available water in reservoirs to cereals and sugar beet. Furthermore, horticultural crops demand high technology and expertise for the successful implementation of localized irrigation, diseases control, marketing, etc. Another limiting factor is the setting up of the minimum cultivated surface in 5 ha as it was established by the Dahír 1-69-29 (July 1969). It imposes an unnecessary rigidity to the system that, in many cases, does not allow attending to the diversity of horticultural production. Another problem is the established tradition of cultivating cereals in the region and, especially, the tendency of the ORMVAT experts to focus attention on major crops as is the case of cereals. Notice that liberalization process was expected to allow farmers to make decisions, but this is useless “per se” if it is not accompanied by official State investments headed up to increase innovation, training, commercialization and technology in the agricultural sector.

Conclusions

The study of the socioeconomic performance of the main crops and their multitemporal monitoring by means of object-based remote sensing techniques using Landsat imagery has proven to be a useful tool to help evaluate the effects of agricultural policies at a regional scale, but it should be supplemented with field-based data. Multiscale segmentation and supervised classification with classifier training based on tabular data, which could be called in the context of this paper training and validation based on non-georeferenced data, turned out to be an original method highly recommended for the multitemporal reconstruction of crops and land cover spatial distribution in the absence of a georeferenced ground truth. From that analysis, it can be stated that ORMVAT still gives priority to crops such as cereals, sugar beet and forage crops which are less profitable from a socioeconomic point of view. In this sense, the socioeconomic impact indicators adopted in this paper have enabled an integrated assessment of productivity for each crop in terms of efficiency in the use of a scarce resource such as irrigation water. The social component of the index (SEP) makes it very useful as an indicator for assessing the sustainability of a farming system. The results coming from this study substantiate the hypothesis that the stagnation stage of development which is suffering this region could be partially explained by the adoption of crops with a low socioeconomic productivity. This fact would be aggravated by a numerous of contributing factors like the succession of dry years, which effect turns out to be very sensitive in arid areas, together with various endemics weaknesses of the area such as lack of commercial connection and logistics systems, lack of state initiatives to advise and introduce new farming techniques and rigidity of the system related to the minimum cultivated surface. All these circumstances have obliged the farmers to adopt more traditional crops, thus endangering the future of one of the richest zones of Morocco in natural resources.

Summing up, remote sensing and OBIA techniques could be a very interesting methodological framework for multitemporal mapping of crop irrigation areas in arid regions such as Tadla Azilal. In this sense, it could be considered a true work of “agricultural systems archaeology” based on the appropriate temporal and spatial resolution satellite imagery from Landsat series.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Assessment of cattle fattening and marketing system and constraints affecting cattle fattening in Central Southern Region of Ethiopia

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A study was conducted to characterize cattle fattening and marketing system and to assess constraints affecting cattle fattening by interviewing 165 farmers in Central Southern Region, Ethiopia. Fattening length and age for oxen were 4 months and 7 years, respectively. Light white and red were the best color of cattle selected for fattening whereas black color was not recommended. Majority of farmers fattened castrated male cattle and marketed only during the main holidays. The price was highest from September to April. Farmers, traders and brokers were the 1st, 2nd and 3rd ranked marketing actors, respectively. Feeds used for supplementation were false banana, sweet potato, sugar cane, wheat bran, improved forages, mineral soils and residuals of coffee and beverages. Lack of capital was the main constraint to begin fattening. The results showed that age of fattening oxen was very old and most of the feed resources were locally available. The use of improved forages and concentrate feeds for cattle fattening is a growing practice, however, further work is needed to develop a cost effective feeding strategy by combining improved and locally available feed resources. Non-seasonal fattening and marketing, easy system of credit provision and controlled marketing system were needed.

Key words: Cattle fattening and marketing, selection criterions, marketing season, marketing actors, fattening duration, central southern Ethiopia.

INTRODUCTION

The agricultural sector plays an important role in the overall development of the economy of Ethiopia. The sector plays a major role in the national economy and it is the source of income and employment for the rural population (Negussie, 2001). The sector account for 46% of the gross domestic product (GDP) and livestock contributes 30% to the agricultural GDP and 19% to the export earnings (Azage and Alemu, 1998). Meat production and consumption is important in the Ethiopian economy and ruminants contribute over 3.2 million tons,

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Table 1. Type of color, sex and castration of the animals selected for fattening in the study area (%).

Parameter	Welaita (n=32)	Hadiya (n=38)	*KT (n=34)	Sidama (n=31)	Gedio (n=30)	Mean (N=165)
Color						
Red	56.20	26.30	16.00	6.50	38.10	28.62
Bulla	40.30	63.20	80.00	90.30	57.90	66.34
Black	0.00	0.00	0.00	0.00	0.00	0.00
Others	3.50	10.50	4.00	3.20	4.00	5.04
Castration						
Castrated	96.90	100	100	90.3	5.30	78.50
Not castrated	3.10	0.00	0.00	9.70	94.70	21.50
Sex						
Male	71.90	86.80	82.40	96.80	94.70	86.52
Female	0.00	0.00	0.00	0.00	0.00	0.00
Both	28.10	13.20	17.60	3.20	5.30	13.48

*Kembata-Tembaro zone.

representing over 72% of the total meat production (Nigusse, 2001).

Crop-livestock mixed farming system is one of the predominant farming systems in the rural community of the central southern region. Shortage of land due to population pressure pushing many more farmers either to intensify the cropping system and or diversify the system using other integrated activities. Cattle fattening is among an integral componential activities (Getahun, 2008). Despite good fattening potentials associated with ample feed resources, market access, indigenous animal with huge potential for meat production have been expected in the region, because little attention to livestock development in general and animal fattening in particular and much has not been studied about the utilization of available feed, fattening practices and marketing system of animals in the region. Therefore, understanding the role and function of local production and marketing system as well as production constraints is of considerable relevance in future research and development directions and strategies would be given due priority. The objective of this study was thus to characterize and examine cattle fattening and marketing system and to asses constraints that may be required in designing possible interventions for more market-orientation of the production system.

MATERIALS AND METHODS

Description of the study area

The study was conducted in five selected zones of Southern Nation Nationalities and Peoples Regional State. The zones were Welaiyta, Kembata-Tembaro (KT), Hadiya, Sidama and Gedio. The zones have different language and culture. The farming system of the zones was crop-livestock mixed farming system and were highly populated areas with a maximum of about 670 persons per km^2 (except in Gedio zone,Wonago is 900 persons per km^2) (Million, 2003). The number of cattle population in Ethiopia were 53,382,194 of which 761,197, 317,239, 207,7636, 160,615, 767,154 were found in Hadiya, Kembata-Tembaro, Sidama, Gedio and Wolayita zones, respectively (CSA, 2011).

Study technique

The study was undertaken in 2 districts of each Wolayita, Kembata-Tembaro and Hadiya zones, one district of each Sidama and Gedio zones. The districts and farmers were selected purposefully based on their fattening experiences. A total of 165 farmers in which 32, 38, 31, 34 and 30 heads of households' from Welayita, Hadiya, Sidama, Kembata-Tembaro and Gedio zones, respectively, were selected and interviewed using pre-tested structured questioner.

Data analysis

The data collected were analyzed using SPSS (version 16). Descriptive statistics such as mean and percentages were used to summarize data as required. In addition single factor ANOVA test was employed to analyze differences among the five study zones of the region with respect to various quantitative response variables. When ANOVA declares significance, mean comparison was made using Duncan Multiple Range Test.

RESULTS

Criterions to select cattle for fattening

As indicated in Table 1, the majority of the respondents

Table 2. Fattening duration (months) and age (years) of fattening oxen in the study area.

Parameter	Welaita (n=32)	Hadiya (n=38)	*KT (n=34)	Sidama (n=31)	Gedio (n=30)	Mean (N=165)
Duration	3.56±0.76^{a}	3.75±1.05^{a}	4.0±1.0^{a}	4.26±1.20^{ab}	4.74±1.97^{b}	4.00±1.24
Age	7.23±3.12^{b}	7.12±1.39^{b}	7.65±1.99^{b}	6.87±2.11^{b}	5.42±1.57^{a}	6.92±2.22

^{abcd} means with different superscript across rows are significantly (p<0.05) different, *KT= Kembata-Tembaro zone.

Table 3. Season of marketing (%), rank of marketing actors and the role of brokers (%) in marketing fattened animals in the study areas.

Parameter	Welaita (n=32)	Hadiya (n=38)	*KT (n=34)	Sidama (n=31)	Gedio (n=30)	Mean (N=165)
Marketing season (%)						
Main holidays	56.20	50.00	58.80	74.20	94.70	66.78
main holidays and non holidays	43.80	50.00	41.20	25.80	5.30	33.22
Rank of marketing actors						
Farmer	2	2	1	1	1	1.40
Trader	1	1	2	2	2	1.60
Broker	3	3	3	3	3	3.00
Brokers have negative role	96.9	97.40	70.60	77.40	84.20	85.30

*Kembata-Tembaro zone.

(66.34%) indicated that light white color was the best animal color selected for fattening followed by the red color, 28.62%. None of the farmers recommended selecting black colored animals for fattening purpose. Castration of animals was also a criterion for fattening in the region. Accordingly 78.50% of the respondents castrate their animals for fattening while the remaining 21.50% of the respondents do not recommend castration. However, farmers castrating their oxen for fattening were significantly (p<0.05) lower in Gedio zone than other zones. Almost all of the farmers (94.70%) in Gedio zone do not castrate their oxen for fattening. Majority of the respondents (86.52%) fatten only male cattle, where as 13.48% of the respondents fatten both male and female animals. None of the farmers fatten only female cattle in the study area. In addition to the above criterions, all farmers purchased fattening cattle of tall height, good body condition and big and stand-high hump.

Smallholder farmers in the region commonly fatten mature and much older animals (7 years old) for short durations (usually four months) (Table 2).The fattening duration of oxen in Gedio was significantly (p<0.05) higher than that of Welayta, Hadiya and Kembata – Tembaro but it was similar to Sidama. The fattening duration of oxen in Wolaita, Hadiya and Kembata – Tembaro and Sidama were similar. As indicated in Table 2, the average age of fattening oxen was 6.92 years. The average fattening age of oxen in Welayta, Hadiya, Kembata –Tembaro and Sidama zones were similar but significantly (p<0.05) higher than that of Gedio zone.

Season of marketing and marketing actors of fattened cattle

As indicated in Table 3; 66.78% of the respondents market their fattened animals during the main holidays whereas about 33% during both the main holidays and non-holidays seasons. In the region, there was no well organized cooperatives that perform fattening and marketing of animals. There were different factors that constrain the market price of fattened animals in the region. Among these, season of marketing and marketing actors are the two important factors. All of the respondents in the region reported that the market price of fattened animals was highest from September to April. None of the farmers use scientific measurements to weigh the live weight of animals when purchasing and selling.

In the region, the key actors of marketing fattened animals are Farmers (1st ranked) Traders (2nd ranked) and Brokers (3rd ranked). Even though brokers are the third ranked actors in decision making to market fattened animals, they have a crucial role in bargaining for traders and farmers by getting about 100.00 Ethiopian birr (ETB) per fattened cattle on average from both sides (that is,

Table 4. Types of feeds and feeding system of fattening animals in the study area (%).

Parameter	Welaita (n=32)	Hadiya (n=38)	*KT (n=34)	Sidama (n=31)	Gedio (n=30)	Mean (N=165)
Method of feed provision						
Stall feeding	84.40	78.90	94.10	90.30	100	89.54
Grazing only	0.00	0.00	0.00	0.00	0.00	0.00
Stall feeding and grazing	15.60	21.10	5.90	9.70	0.00	10.46
Feeds used for supplementation						
Enset (false banana)	75.00	74.00	88.00	77.40	89.50	80.78
Sweet potato	78.00	20.00	88.00	78.00	89.50	70.70
Sugar cane	30.00	65.00	20.00	73.40	78.50	53.38
Wheat bran	62.50	86.80	76.50	90.30	57.90	74.80
Residuals and mineral soils	100.00	71.10	76.00	90.30	100.00	87.48
Improved forages	34.40	34.20	76.50	77.40	26.30	49.76

*Kembata-Tembaro zone.

they have a role in decreasing and increasing the price of fattened animals). Accordingly, about 85% of the respondents reported that the brokers have a negative role in marketing fattened animals. While about 14.70% of the respondents believe that brokers are resource persons for they know information about the price situation on that marketing day.

Feeds and feeding system of fattening cattle

Farmers in the surveyed areas have experiences in supplementing locally available high nutritious feeds. In the region, all respondents responded that major feed resources for their fattening animals and used as a basal diet are crop residues and natural pasture. As indicated in Table 4, supplementary feeds for fattening animals were whole parts of enset (false banana) (89.54%), sweet potato vine and tuber (70.70%), sugar cane (53.38%), mineral soils and residuals of coffee and beverages (87.47%) and improved feeds especially desho grass (*Brachiariabrizantha)* (49.76%), Napier grass (*Pennisetumpurpureum*) (49.76%) and concentrate feed (wheat bran) (74.80%). Farmers in the region do not feed their animals with silage and urea treated crop residues. Majority of the respondents (89.54%) provide both basal and supplementary feeds in a stall feeding system where as 10.46% of the respondents alternate the feeding systems in the form of stall feeding and grazing (Table 4). Farmers in the region reported that during the first few weeks of fattening period or prior to actual fattening period, farmers having enough private grazing lands keep their fattening animals on good and enclosed pasture land for a short time per day for exercising, herbage consumption purpose, take a time to clean the barn and to reduce the feed cost.

Constraints affecting fattening of cattle

Farmers have put different ranks for the most known constraints of fattening in the study area. Lack of initial capital is the first ranked constraint whereas lack of credit provision, unavailability and poor quality of feed, lack of awareness and land shortage were the second, third, fourth and fifth ranked constraints of cattle fattening in the region, respectively.

DISCUSSIONS

Criterions for cattle to select for fattening and fattening length

Consistent with Takele et al. (2009) and BoARD (2004), fatteners in Welaita and northern part of Ethiopia select fattening cattle of tall height, good body condition and big and stand-high hump in addition to coat color and sex. Contrary to these results, almost all traders in Amhara region of Ethiopia do not take coat color as a criterion for selection of beef animals (Belete et al., 2010). The present findings find similarities with Takele et al. (2009) and BoARD (2004) who reported that cattle feeders fed cattle usually for 4 months in welaita area of southern Ethiopia and Bahrdar area of northern Ethiopia, respectively. In contrary, MOA (1996a) reported that the age and duration of fattening cattle in western part of the country were one years old and for 6 months, respectively. According to Habtemariam (2000), farmers in east Ethiopia fed oxen for more than one year which is also significantly exceeds the average fattening length in southern parts of Ethiopia.

Season of marketing and marketing actors of fattened cattle

Majority of farmers in the region marketed their fattened cattle during the main holidays. This is in agreement with the reports indicated by Takele et al. (2009) who reported that cattle fattening is a seasonal operation in welaita with a peak from June to September and this is governed by seasonality pattern of feed availability and main holidays. Inconsistent to our findings cattle are, however, fattened throughout the year with a peak during dry season in Malawi (Nkhonjera et al., 1988).

None of the farmers use scientific measurements to weigh the live weight of animals while purchasing and selling was in good agreement with the findings of Alemayehu (2003) who reported that marketing of livestock is not determined on the basis of weight and which is unfavorable marketing system and discourages price on the producers' side. The market price of fattened cattle was highest from September to April. Reason for this might be due to the availability of the main holidays in September (*meskel),* December *(x-mas)* and in April (Easter) (Belachew, 2004; Takele et al., 2009) and the coffee crop gets in to the hands of traders then, and their demand for meat at that time is consequently high from November to March (Barry and Ejigu, 2006). Moreover, the high income level of farmers in that season increases meat consumption which has direct influence on the price of fattened animals. As contrary to this report, the market price of fattened animals is highest from May to September in Amhara Region of Ethiopia (Belete et al., 2010). Among the marketing actors, brokers have a crucial role in bargaining for traders as well as farmers or producers by getting about 100.00 birr per a fattened cattle on average from both sides. This is significantly different from broker's fee in Bale livestock market of the same country which was ETB 10/head of cattle (Getachew et al., 2008). In the region, so far there is no well organized cooperatives that perform fattening and marketing of animals. This indicates that marketing systems have not been generally administered (Azage et al. (2006).

Feeds and feeding system of fattening cattle

Major feed resources used as a basal diet for fattening cattle were crop residues and natural pasture which is in line with the findings of Takele et al. (2009) in southern region and Belete et.al, (2010) in Amhara region of Ethiopia. Consistent to Takele et al. (2009) supplementary feeds for fattening cattle were whole parts of false banana, sweet potato vein and tuber, sugar cane, mineral soils and residuals of coffee and beverages. However, in the present study farmers supplement fattening cattle with improved forages especially desho grass (*Brachiariabrizantha)*, Napier grass (*Pennisetumpurpureum*) and concentrate feed especially wheat bran which is not in agreements with Takele et al. (2009) which might be due to the renewed interest of farmers to introduced improved forages and feeds in various parts of the country (Azage et al., 2006). Farmers in southern Ethiopia provide both basal and supplementary feeds in a stall feeding system which is in close agreement with Fourth Livestock Development Project, (MOA, 1996a) which indicated that Hararghe fattening system is largely based on cut-and-carry feeding of individually tethered animals and grazing is rare.

The present study indicated that prior to actual fattening period, farmers having enough private grazing lands keep their fattening cattle on good and enclosed pasture land for a short time per day for exercising, herbage consumption purpose, barn cleaning, to put the animal in better condition while draught and to reduce the feed cost and are in agreement with Takele et al. (2009).

Constraints affecting fattening of cattle

In agreement with the present study, Belete et al. (2010) reported that shortage of capital was the first constraint to cattle fattening in Amhara region of Ethiopia. Credit provision was a crucial problem to animal fatteners in the region which might be due to sources of financing, generally involving subsidized, low interest credit; tend not to allow small holders to borrow money unless they are organized in groups or through cooperative arrangements (Azage et al., 2006). Getnet (2003) reported that feed quality and quantity is the main limitation to animal production in Ethiopia which is in agreement with the present findings. In line with the present study, the central southern region is highly populated with a maximum of about 670 persons per km^2 and therefore intensification is probably a better path for this area since there is no possibility for further land expansion (Million, 2003).

Conclusions

The results showed that age of fattening oxen was very old and most of the feed resources were locally available. The use of improved forages and concentrate feeds for cattle fattening is a growing practice. Initial capital, credit provision, feed availability and quality and lack of awareness were the most constraint factors to fatten cattle. Therefore, further work is needed to develop a cost effective feeding strategy by combining improved and locally available feed resources. Moreover, non-seasonal fattening and marketing, easy system of credit provision and controlled marketing system were needed to enhance the performance of cattle fattening and marketing in the region.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

A comparative analysis of distinctness, uniformity and stability (DUS) data in discriminating selected Southern African maize (*Zea mays* L.) inbred lines

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The ability to discriminate germplasm is important for plant breeding as well as for plant variety protection. To achieve this, plant breeders have been using molecular, physiological and biochemical markers in discriminating and grouping of genotypes. Breeders have been looking for effective, quick and cheaper ways of grouping germplasm. Therefore this study was carried out to assess the ability of the traits used for determining the distinctness, uniformity and stability (DUS) of new plant varieties and agro-morphological characteristics for differentiating Southern African maize inbreds. In this study, 18 maize inbred lines were assessed for their variation based on 25 agronomic and 12 DUS traits. The maize inbred lines were grouped differently based on qualitative or quantitative traits or when combined. The correlation between the qualitative and quantitative similarity matrices was low (r=0.048) and non-significant. This indicated that both qualitative and quantitative traits should be used for effective maize inbred line discrimination. Both qualitative and quantitative similarity matrices were highly significantly (p<0.001) and highly correlated to mixed data (r=0.82 and r=0.61 respectively). The grouping of the inbred lines based on Principal Component Analysis (PCA) was similar to the similarity matrix of the mixed data. The first principal component, which explained 27.8% of the total variation, was due to grain yield and productive parameters. The second component, explaining 13.2% of the total variation was due to number of tassel branches (TBNo) and tassel length (TL). The Shannon diversity index showed that the inbred lines were diverse in days to silking, ear diameter, days to maturity, shelling percentage and leaf colour. It is concluded that for effective discrimination of maize inbred lines both agro-morphological and DUS traits should be used especially when few inbreds are being considered.

Key words: Maize *(Zea mays* L.), cluster analysis, repeatability, phenotypic characterisation, distinctness, uniformity and stability (DUS) traits.

INTRODUCTION

The development of inbred lines and identification of their best hybrid combinations is critical in an inbred-hybrid oriented breeding programme (Ristanovic et al., 1987). However, the process of developing and selecting inbred lines is costly and time-consuming as extensive yield trials are required to evaluate F_1 performance to identify the parental lines combinations. Thus breeders make several crosses and evaluate the F_1 to identify inbred lines that are heterotic. In this case, inbred lines with desirable agronomic traits are selected for hybridisation and are maintained (Bertan et al., 2007). Hence, phenotypic diversity of parental lines is necessary to achieve high heterosis in hybrids. Therefore, a breeding programme with diverse inbred lines is most likely to deliver superior hybrids.

Morpho-physiological markers have been used to study the genetic diversity in maize (Beyene et al., 2005; Xiang et al., 2010). In addition, morphological characters have been recognized to constitute universally undisputed descriptors for varietal characterization of crop species and establishing the distinctness, uniformity, and stability (DUS) of crop species in Plant Variety Protection (PVP) Systems (Begum and Kumar, 2011). The traits used in assessing crop varieties for DUS have been carefully selected taking into account the plasticity of morphological characteristics and thus are efficient for comparing varieties (Law et al., 2011). However, the measurement of morphological traits is expensive, requiring more space, time consuming (Smykal et al., 2008) and trait expressivity is affected by environment (Bonow et al., 2009) due to gene x environment interaction (Law et al., 2011a). The limitation of using morphological traits is further compounded by the reduction in the variability of morphological traits in elite germplasm (Bonow et al., 2009; Gunjaca et al., 2008) caused by inbred line recycling (Reif et al., 2010; Ristanovic et al., 1985) and essential derivation (White et al., 2006). Pedigree breeding has also been implicated for reducing genetic variability of maize (Newton et al., 2010; Reif et al., 2010). The reduction in genetic and morphological variability makes it difficult to distinguish varieties (Begum and Kumar, 2011; Bonow et al., 2009). Despite this drawback, phenotypic characterisation of inbred lines is still important for breeding high yielding genotypes (Hung et al., 2012) as heterosis has been reported for morphological traits in sub-tropical maize (Iqbal et al., 2010). Recently, it has been shown that morphological traits are still important in maize characterisation and discrimination (Law et al., 2011a; Law et al., 2011b). Furthermore, there is a genetical basis for morphological differentiation in plants (Cavender-Bares and Pahlich, 2009). In this respect, a method to identify traits that are reliable, robust with high discrimination ability has been developed and described (Law et al., 2011b). All these are aimed at improving the methodology of identifying parents for the generation of superior hybrids.

To improve maize productivity in Zambia, a comprehensive maize breeding programme was initiated in 1979 (Mungoma, 1999). At that time, the breeding programme had a task of developing maize hybrids suited to all agro-ecological zones of Zambia. This meant having a breeding programme that ensured continuous supply of inbreds with better performance and adaptation. Therefore the use of improved versions of elite lines inbreds was practiced (ZARI, 1987). Inbred line improvement was achieved by recurrent selection. However, recurrent selection reduces the number of alleles and increases genetic differentiation at the expense of loss of heterozygosity (Solomon et al., 2010). Although the improved maize inbred lines that were developed produced hybrids with improved performance and wide the adaptation, there is little information available on the changes in genetic diversity. Monitoring the changes in genetic diversity of elite inbreds, as time progresses, is important to avoid crop vulnerabilities associated with a narrow genetic base as well as for maintaining genetic gain (Smith, 2007). This leads to effective management of genetic diversity which is necessary for increased crop productivity (Smith, 2007).

Therefore, the aim of the study was to generate information that will result in the effective utilization of historical elite maize inbred lines. The objectives of the study were to characterise and quantify genetic diversity of founder lines using agronomical and DUS traits.

MATERIALS AND METHODS

A total of eighteen (18) maize inbred lines from Zambia, Zimbabwe and CIMMYT- Zimbabwe were used for the study (Table 1). The trial was conducted at Seed Control and Certification Institute (SCCI) under well fertilised conditions, using a randomised completed block design. During the growing period, data on several morphological traits were collected. The traits were selected from those used by the Variety Testing, Registration and Protection Section of the SCCI in their trials. These traits are modified from the Union for the Protection of New Plant Varieties (UPOV) DUS test guidelines for maize (UPOV, 2009). The characteristics are shown in Table 2.

Data analysis

The mean values for eleven morphological characters and scaling values for physiological characters were used to assess the dissimilarity between inbred lines. The matrix of all the quantitative traits was first standardised before calculating the Euclidean similarity distance matrix among the inbreds. A dendrogram was constructed using Ward to provide a general visualisation of the relationship between inbreds based on quantitative traits using Minitab 14 statistical software. The Ward's method of clustering was used as it has been shown to be in concordance with pedigree data when phenotypic traits based on the UPOV descriptor are used

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Table 1. List and sources of maize inbred lines used in the study.

S/No.	Genotype	Pedigree	Source
1	J185	SYN Temperate A-SR-F2-4	CIMMYT - Zimbabwe
2	K64-r	K64	AREX - Zimbabwe
3	L12	Yugoslav germplasm	ZARI
4	L1212	Yugoslav germplasm L9 version	ZARI
5	L1214	L12 version	ZARI
6	L151	V01/87923-x-7575-3-3-1-2-3-1	ZARI
7	L152	V01/87923-x-7575-3-3-1-2-3-2	ZARI
8	L2	Yugoslav germplasm	ZARI
9	L211	L2 version	ZARI
10	L3233	L3233 version	ZARI
11	L3234	unknown	ZARI
12	L334	Yugoslav germplasm	ZARI
13	L5522	Contaminated SC selection	ZARI
14	L911	Yugoslav germplasm L9 version	ZARI
15	L913	Yugoslav germplasm L9 version	ZARI
16	L917	Yugoslav germplasm L9 version	ZARI
17	N_3	Salisbury White germplasm	AREX - Zimbabwe
18	SC	Salisbury White germplasm	AREX - Zimbabwe

Table 2. Characteristics used in DUS testing of inbred lines and their acronyms in brackets.

SCCI S/N[@]	Characteristic	Options		Mode of assessment
17	Ear: Days 50% silk emergence (Dsilk)	Very Early (<60 days) Early (60-65) Medium (65-70) Late (70-75) Very late (>75)	1 3 5 7 9	Calculate: From seedling emergence to when 50% of the plants in a plot have exposed their silk (VG)
18*	Ear: Silk anthocynin colouration (SilkColor)	Absent Present	1 9	Visual (VG)
19*	Ear: Intensity silk anthocynin colouration (SilkColorInt)	Very weak Weak Medium Strong Very strong	1 3 5 7 9	Visual (VG)
20	Ear: Anthocynin coluoration of ear-sheath (EarSheathColor)	Absent Present	1 9	Visual
21	Ear: Intensity anthocynin of ear-sheath (EarSheathInt)	Very weak Weak Medium Strong Very strong	1 3 5 7 9	Visual
22[S]	Tassel: Glume anthocynin coloration (TGlumeAntho)	Absent Present	1 9	Visual

Table 2. Contd.

23^{S}	Tassel: Intensity of anthocynin on glume (TGlumeInt)	Very weak Weak Medium Strong Very strong	1 3 5 7 9	Visual
24^{+}	Tassel: Ring at base of glume (TGRingAntho)	Absent Present	1 9	Visual
25	Tassel: Intensity of glume ring (TGRingInt)	Very weak Weak Medium Strong Very strong	1 3 5 7 9	Visual
27	Leaf: Attitude (LfAttitude)	Rectilinear Slightly recurved Recurved Strongly recurved Very strongly recurved	1 3 5 7 9	Visual
28	STEM: Node anthocynin colour (NodeColor)	Absent Present	1 9	Visual
29	STEM: Intensity of node anthocynin colour (NodeColorInt)	Very weak Weak Medium Strong Very strong	1 3 5 7 9	Visual
30	STEM: Internode anthocynin colour (InternodeColor)	Absent Present	1 9	Visual
31	STEM: Intensity of internode anthocynin colour (InternodeInt)	Very weak Weak Medium Strong Very strong	1 3 5 7 9	Visual
32	Leaf: Sheath Anthocynin coloration (LfSheathColor)	Absent Present	1 9	Visual
33	Leaf: Intensity of sheath Anthocynin colouration (LfSheathInt)	Very weak Weak Medium Strong Very strong	1 3 5 7 9	Visual
34	Leaf: Hairs on margin of sheath (LfMarginHair)	Very weak Weak Medium Strong Very strong	1 3 5 7 9	Visual

Table 2. Contd.

35	Leaf: Colour (LfColor)	Light green Medium green Dark green	3 5 7	Visual
36	Leaf: Length of the leaf below first cob (cm) (LfLngth)	Very short (<85 cm) Short (85-90) Medium (80-95) Long (95-100) Very long (>100)	1 3 5 7 9	Measure
37	Leaf:Width of the leaf below first cob (cm) (LfWidth)	Narrow (<9.8 cm) Medium (9.8-12) Broad (>12)	3 5 7	Measure
38*[+]	Tassel:Angle between main axis and lateral branches (TBAngle)	Small (<45°) Medium (~45°) Large (>45°)	3 5 7	Visual (Right angled aid)
39*[+]	Tassel: Attitude of lateral branches (TBAttitude)	Rectilinear Slightly Recurved Recurved Strongly recurved Very strongly recurved	1 3 5 7 9	Visual
40*	Tassel:Number of primary lateral branches (TBNo)	Very few (<10) Few (10-15) Medium (15-20) Many (20-25) Very many (>25)	1 3 5 7 9	Count
41	Tassel: Length of main axis above lowest lateral branch (cm) (TLB)	Very short (<30 cm) Short (30-35) Medium (35-40) Long (40-45) Very long (>45)	1 3 5 7 9	Measure
42*	Tassel: Length of main axis above uppermost lateral branch. (cm) (TUBL)	Very short (<20 cm) Short (20-25) Medium (25-30) Long (30-35) Very long (>35)	1 3 5 7 9	Measure
44	Maturity:Days to black-layer (Maturity)	Very early (<100 day) Early (100-120) Medium (120-130) Late (130-140) Very late (>140)	1 3 5 7 9	Calculate
45	Ear: Height of insertion (cm) (EH)	Very low (<50cm) Low (50-80) Medium (80-110) High (110-140) Very high (>140)	1 3 5 7 9	Measure (MS)

Table 2. Contd.

46*	Plant:Height (Base to tip of tassel) (cm) (PH)	Very short (<150 cm) Short (151-200) Medium (201-240) Tall (241-300) Very tall (>301)	1 3 5 7 9	Measure (MS)
50*	Ear: Length without husk (cm) (EL)	Very short (<10cm) Short (10-15) Medium (15-20) Long (20-25) Very long (>25)	1 3 5 7 9	Measure (MS)
52	Ear: Diameter (in middle) (cm) (ED)	Very thin (<3.5 cm) Thin (3.5-4.0) Medium (4.0-4.5) Thick (4.5-5.0) Very thick (>5.0)	1 3 5 7 9	Measure (MS)
53+	Ear: Shape (Earshape)	Conical Slightly conical Cylindrical	1 2 3	Visual (VG)
54	Ear: Number of grain-rows (ERNo)	Very few (<10 rows) Few (10-12) Medium (12-14) Many (14-16) Very many (>16)	1 3 5 7 9	Counting (MS)
55	Ear: Number of grains per row (GRNo)	Very few (<30) Few (30-35) Medium (35-40) Many (40-45) Very many (>45)	1 3 5 7 9	Counting (MS)
56*	Ear: Type of grain (in middle third of ear) (Gtype)	Flint Flint-like Intermediate Dent-like Dent	1 2 3 4 5	Visual (VG)
63	Grain: 100 seed weight at 14%MC (Hswt)	Light Medium Heavy	3 7 9	Measure (MG)
65	Grain: Yield (Kg/ha) at 14%MC (GY)	Very Low (<1.0t/ha) Low (1.0 - 3.0t/ha) Medium (3.0 - 5.0 t/ha) High (5.0 - 7.0t/ha) Very high (>7.0t/ha)	1 2 3 4 5	Measure (MG)

Table 2. Contd.

66	Grain: Shelling % (shell)	Poor (<50%)	3	Measure (MG)
		Fair (50 - 80%)	5	
		Good (>80%)	7	

*Characteristics that should be used every growing period for the examinations of all varieties and should always be included in the description of the variety, except when the state of expression of a preceding characteristic or regional environmental conditions render this impossible; + Characteristics that are scored with the help of a drawing or photo graph; @SCCI S/N: Serial number of the characteristic in the SCCI field guide book for DUS evaluation; MG = single measurement of a group of plants or parts of plants; MS = measurement of a number of individual plants or parts of plants; VG = visual assessment by a single observation of a group of plants or parts of plants.

(Babić et al., 2008). Qualitative traits and a combination of qualitative and quantitative traits were used to generate the similarity between inbred lines based on the Gower similarity matrix using XLSTAT 2013 software (excel addin software). Then the similarity matrix was submitted to MEGA 5 (Tamura et al., 2011) for clustering using the UPGMA for qualitative trait only. The Gower similarity matrix for the combined qualitative and quantitative traits was submitted to the NTSYSpc version 2.21 L software for neighbour joining clustering. The Quantitative data were also subjected to principal component analysis (PCA) to identify traits that are most discriminatory, using the Minitab 14 statistical software. Similarly, Furthermore, the principal coordinate analysis (PCoA) was performed on the qualitative traits using the MVSP for Windows (Kovach, 2007).

The euclidean distance was computed from data between two individuals *i* and *j*, as:

$$d_{ij} = [\sum_{k=1}^{K}(x_{ij} - x_{jk})^2]^{1/2}$$

Where d_{ij} = euclidean distance, x_{ij} and x_{jk} are the standardised values for the ith character of the j^{th} and k^{th} inbred lines, respectively.

The Gower's coefficient (Gower, 1971) permits the simultaneous use of variables of different scales of measurement. It is calculated as:

$$S_{ij} = \{\sum_{k=1}^{n} S_{ijk} W_{ijk}\} / \sum_{k=1}^{n} W_{ijk}$$

Where S_{ij} = Gower's similarity combining similarities from different traits, S_{ijk} = contribution of k^{th} variable and W_{ijk} = weights of each variable which is usually 1 or 0.

The Shannon-Weaver diversity index (HS) was computed using the phenotypic frequencies, to assess the phenotypic diversity for each trait for all inbred lines (Shannon and Weiner, 1983; Spellerberg and Fedor, 2003). The HS was evaluated as:

$$\text{Shannon diversity index (HS)} = 1 - \sum_{i=t}^{s} P_i [In(P_i)]$$

Where, P_i = is the proportion of inbred lines in the i^{th} class of an n-class character, n = number of phenotypic classes for a character and *In* = natural logarithm.

$$\text{Evenness (J)} = \frac{HS}{\ln S}$$

Where HS = Shannon-Waeaver diversity index and *In* S = natural logarithm of the inbreds richness.

RESULTS AND DISCUSSION

Quantitative traits

Analysis of variance revealed highly significant differences among inbred lines for all the traits except for days to maturity, number of rotten cobs, number of grain rows per cob, ear leaf width (cm), Taxis BelowB, 6 cm upper, 6 cm lower, number of tassel branches, TL long and TUBL short (Table 3). A wide range of expression was also observed for 25 agronomic traits studied. The widest range was exhibited by grain yield (2584 kg/ha) followed by leaf area (467cm^3). The narrowest range was observed for hundred seed weight (0.03 g), and followed by ear diameter (1.16 cm). The widest range exhibited by grain yield was also observed by Beyene et al. (2005). This could be attributed to the breeding programme that was initiated to develop inbred lines that would produce hybrids adapted to a wide range of growing conditions (Ristanovic et al., 1985). This breeding programme was initiated after it was concluded that Zambia needed hybrids for different agro-ecological areas and levels of management. On the other hand, the narrow range of time to maturity indicates that there was a shift to develop varieties with medium to intermediate maturing period, to avert the risks involved with maize production. However, the variation in time to maturity can only be appreciated in testcrosses.

Grain yield was significantly correlated to 36% of the traits (9 out of 25) (Table 4). The highest correlation was observed in ear height (r^2=0.63), and followed by ear leaf width (r^2=0.62). Cobrot was significantly and negatively correlated to grain yield (r^2=-0.61). This implies strengthening the breeding of inbreds that are tolerant to cobrots. The impact of tassel related traits on seed set has been discussed (Chanda et al., 2010). In this study, tassel axis length below the upper branch and tassel axis above the upper branch were negatively correlated to grain yield. This confirms in part the tendency for breeders to select for reduced tassel traits. Similarly, gray leaf spot (GLS) had a small negative impact on grain yield, hence it is needed to develop tolerant lines to GLS to produce hybrids with better yield performance.

Ear leaf has been reported to play a critical role in maintaining grain yield through resource remobilization to

Table 3. Statistical of 25 agro-morphological traits measured in 18 maize inbred lines.

Traits	Mean	Max	Min	Range	Standard deviation	p value	CV%	Repeatability
Days to silking	75.47	81.42	70.65	10.77	2.79	< 0.001	1.6	0.90
Days to maturity	137.03	143.70	129.20	14.50	4.29	0.427	4.1	0.14
Plant height (cm)	175.28	211.53	135.03	76.50	23.03	0.05	11.6	0.57
Ear height (cm)	94.78	137.39	53.09	84.30	21.30	0.036	19.9	0.60
PH to EH ratio	1.92	2.71	1.24	1.47	0.30	0.015	12.8	0.67
Number of rotten cobs	0.48	1.86	0.00	1.86	0.66	0.097	141.7	0.48
Length of tassel axis above the upper branch (cm)	22.17	32.01	15.60	16.41	4.44	< 0.001	10.9	0.83
Ear leaf width (cm)	9.14	11.49	5.51	5.98	1.35	0.275	16.7	0.26
Ear leaf length (cm)	71.11	91.06	36.15	54.91	13.91	0.037	17.4	0.60
Leaf area (cm^2)	494.67	695.63	228.46	467.17	145.11	0.011	22.22	0.69
Ear length (cm)	16.33	19.65	13.65	6.00	1.88	< 0.001	4.2	0.93
Ear diameter (cm)	4.76	5.28	4.12	1.16	0.28	0.003	3.9	0.77
Hundred seed weight (g)	0.04	0.05	0.02	0.03	0.01	< 0.001	11.7	0.86
Grain yield ($kgha^{-1}$)	3869.42	5278.71	2694.21	2584.50	752.21	< 0.001	11	0.81
Gray Leaf Spot	1.20	2.03	0.77	1.26	0.36	0.002	17.3	0.78
Number of grain rows per cob	29.83	33.92	24.94	8.98	2.31	0.095	7.8	0.49
Number of kernels per row per cob	12.08	14.60	9.99	4.61	1.18	< 0.001	5	0.86
Shelling percentage (%)	84.58	89.28	76.54	12.74	3.66	< 0.001	1.7	0.90
Number of tassel branches	14.22	20.77	8.09	12.68	3.39	0.232	27.2	0.31
TL long (cm)	32.36	38.81	26.82	11.99	4.00	0.316	14	0.22
TUBL short (cm)	22.03	25.66	17.84	7.82	2.30	0.588	15.5	0.11
TL short (cm)	3.97	6.96	1.11	5.85	1.64	0.044	37.2	0.58
6 cm lower (cm)	10.86	13.04	8.68	4.36	1.33	0.168	13.5	0.39
6 cm upper (cm)	13.20	15.44	11.14	4.30	1.16	0.763	13.7	0.43
Taxis below (cm)	32.06	40.86	27.35	13.51	3.30	0.384	13.4	0.14

Table 4. Correlation between grain yield and other agronomic traits.

Trait	6 cm Lower	6 cm Upper	Cobrot	Dsilk	ED	EH	EL	ERNo	GLS
Correlation	0.27	0.45	-0.61	0.09	0.56	0.63	0.26	-0.11	-0.24
Probability	0.28	0.06	0.01	0.72	0.02	0.01	0.31	0.68	0.33
Trait	**GRNo**	**HSWT**	**LfA**	**LfL**	**LfW**	**PH**	**PH to EH ratio**	**GRNo**	**TBNo**
Correlation	0.18	0.32	0.55	0.39	0.62	0.49	-0.51	0.18	0.32
Probability	0.48	0.19	0.02	0.11	0.01	0.04	0.03	0.48	0.19
Trait	**TL long**	**TL short**	**TUBL short**	**Taxis BelowB**	**Taxis UpperB**	**maturity**	**shell**		
Correlation	0.43	0.25	0.27	-0.30	-0.12	0.52	0.24		
Probability	0.07	0.33	0.28	0.23	0.64	0.03	0.35		

the grain (Subedi and Ma, 2005). Subedi and Ma (2005) reported yield reductions of 17 to 25% when ear leaf alone is removed and 40 to 50% reduction when all leaves above the ear are removed. We observed a similar trend in the present study. Furthermore, the results indicate that leaf width had the greatest influence than leaf length in this set of inbred lines.

The repeatability was highest for ear length (R=0.93), followed by days to silking (R=0.90) and shelling percentage (R=0.90). Traits of grain yield, number of grain rows per cob, number of grains per row, hundred seed weight, shelling percentage, and length tassel axis above the upper branch had repeatability greater than 0.80. This indicates that all these traits are relatively

Table 5. Genetic dissimilarity matrix of 18 maize inbred lines based on 25 agronomic traits.

	J185	**K64-r**	**L12**	**L1212**	**L1214**	**L151**	**L152**	**L2**	**L211**	**L3233**	**L3234**	**L334**	**L5522**	**L911**	**L913**	**L917**	N3	SC
J185	0.00																	
K64-r	6.12	0.00																
L12	5.95	7.01	0.00															
L1212	7.13	7.95	6.74	0.00														
L1214	6.65	7.57	7.35	5.38	0.00													
L151	8.81	9.16	7.43	5.29	7.53	0.00												
L152	6.10	7.90	6.62	6.98	5.93	7.40	0.00											
L2	7.52	6.86	8.74	8.41	7.44	10.51	9.27	0.00										
L211	6.56	7.19	5.39	5.69	5.70	7.15	6.16	9.08	0.00									
L3233	7.02	7.91	7.38	5.40	5.27	6.23	7.30	7.98	6.94	0.00								
L3234	6.89	7.07	7.75	4.30	4.57	7.42	6.67	8.12	5.63	6.35	0.00							
L334	6.09	4.96	8.11	7.99	7.86	9.46	8.19	4.91	7.40	8.13	7.68	0.00						
L5522	7.18	8.44	6.37	5.26	6.37	4.16	6.39	9.50	6.52	5.54	7.10	9.08	0.00					
L911	7.62	8.12	6.30	6.29	6.33	7.94	7.88	8.16	5.19	7.64	6.61	7.98	7.51	0.00				
L913	5.51	7.01	5.82	4.61	5.89	5.39	6.62	7.33	5.99	5.51	5.99	6.45	5.26	5.91	0.00			
L917	6.63	7.19	6.74	4.90	2.95	7.45	6.64	8.29	4.45	5.72	4.22	8.01	6.16	5.54	6.23	0.00		
N3	7.61	9.93	7.19	5.49	6.65	6.78	7.93	9.19	7.18	5.21	7.27	9.74	5.64	6.54	6.02	6.11	0.00	
SC	8.28	8.34	7.63	7.88	8.21	7.46	7.14	8.17	7.43	7.47	8.50	6.93	8.12	8.65	6.20	8.66	8.44	0.00

easier to improve by direct selection.

The genetic dissimilarity of the inbreds for the agronomic traits based on Euclidean distance is shown in Table 5. The highest dissimilarity was observed between L151 and L2. The closest was between L917 and L1214.

Based on the Euclidean distance and Ward method, 18 lines were assigned into 4 clusters (Figure 1). Cluster I consisted of J185, L12, L152, L913, and SC; Cluster 2 consisted of L151, L5522, L3233, and N3; cluster 3 consisted of L1212, L3234, L1214, L917, L211, and L911; and cluster 4 consisted of K64r, L2, and L334 respectively. Cluster 3 possessed the highest number of genotypes (6), followed by cluster 1 (5). Cluster 4 had 3 genotypes and cluster 2 had 4 genotypes. The average trait performance of the inbred lines in each cluster is shown in Table 6.

Cluster 3 consisted of the highest yielding group, associated with longer days to maturity, low cob placement, longest cob, heavy kernels and large leaf area. The lowest yielding was cluster 4, associated with early maturity, shortest plant height, shortest cob length, smallest leaf area and lightest kernel weight. It was expected that cluster 4 with the highest number of kernels per row and highest number of grain rows per cob could be the highest yielding. This could be attributed to the low density of the kernels (0.023 vs. 0.042).

Therefore, kernel density exhibited its importance when developing inbreds and thus should be used as an effective parameter for line improvement.

Qualitative traits

The intensity of node colour was the same for all the 18 inbred lines; therefore the trait was removed from the analysis. The variation of the inbreds based on qualitative traits is shown in Table 7. A pair wise comparison was carried out to identify characters that clearly distinguished the inbreds. A variety is said to be clearly distinct from another variety if the difference is more than at least one state (UPOV, 2009).

A pairwise comparison of the traits indicated that grain type is the most distinguishing and ear shape is the lowest distinguishing (Table 8).

The intensity of internode colour, glume ring colour, ear sheath colour, tassel glume colour and leaf sheath colour were the most predominant in

Table 6. Agronomic characteristics of the clusters.

Cluster	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Days to silking	77.4	77.0	74.7	71.8
Days to maturity	138.0	140.0	136.8	131.3
Plant Height (cm)	174.9	179.5	188.4	142.5
Ear Height (cm)	85.1	110.7	101.5	67.7
PH to EH ratio	2.2	1.7	1.9	2.1
Number of rotten cobs	0.6	0.1	0.1	1.4
TaxisUpperB (cm)	26.4	20.2	22.8	18.7
Leaf width (cm)	8.3	10.0	9.7	7.8
Leaf length (cm)	58.9	82.5	75.9	59.0
Leaf area (cm^2)	370.3	619.6	551.3	339.0
Ear length (cm)	16.7	18.6	15.0	14.7
Ear Diameter (cm)	4.5	4.8	5.0	4.6
Hundred seed weight (g)	0.038	0.042	0.033	0.023
Grain yield ($kgha^{-1}$)	3183.8	4244.8	4429.8	3037.3
Gray leaf spot score	1.1	1.3	1.1	1.3
Number of grains per row	29.0	30.9	28.6	31.5
Number of rows per ear	11.9	11.0	12.4	13.5
Shelling percentage (%)	82.4	82.6	87.5	84.9
Number of tassel branches	13.3	13.0	17.0	11.9
TL long (cm)	33.1	30.5	34.8	29.6
TUBL short (cm)	22.1	21.4	23.0	21.0
TL short (cm)	3.2	3.4	5.1	3.6
6 cm lower (cm)	11.5	11.9	10.4	9.2
6 cm upper (cm)	13.4	13.6	13.5	11.5
TaxisBelowB (cm)	35.6	31.7	31.3	29.5

the inbred lines (Table 9). According to the study, it is evident that most of the genotypes have absent/very weak intensity of silk colour, internode colour, glume ring colour, ear sheath colour, tassel glume colour and leaf sheath colour.

It is also evident that ear shape, hairiness of leaf margin, leaf colour, attitude of tassel branches, glume ring colour, grain type and leaf attitude can be used for discriminating maize inbred lines. Furthermore, it can be said that there has been a tendency to develop maize inbred lines that are dent or dent-like or flint with slightly conical (56%) and cylindrical (28%) ears. Due to breeding for the stay green trait, there has been a tendency for developing genotypes with dark green leaves (56%) with only 16% being light green.

The similarity distance based on qualitative traits showed that the longest distance (12.00) was between L3234 and L911, followed by L334 and L911 (11.58), while the shortest distance (2.45) was between L3234 and L334 and L3233 and K64r, followed by that between L12 and SC (2.83) (Table 10). The inbreds were clustered into two major groups, with group 2 having two sub-clusters (Figure 2). Cluster 1 had four genotypes while the rest were in cluster 2 with four in cluster 2a (Figure 2).

Qualitative and quantitative traits

The Gower similarity coefficient executed in XLSTAT 2013, an excel adding software, allows the analysis of mixed data. The longest distance observed was between L911 and L334 (14.06) and the least between L917 and L1214 (5.54). Inbred line L1212 was also closer to L3234 (5.96) (Table 11). The inbreds were clustered into two major groups, A and B (Figure 3), each with two sub-groups. Inbred lines N3, L3233 and SC were grouped together in cluster III. N_3 and SC are the original heterotic groups used in Southern Africa, their derivatives being L3233 and L5522 respectively. Thus we expected N_3 and L3233; and SC with L5522 to be closer.

It was expected that sub-lines would be clustered together with the original lines. For example, L12, the original line was not grouped together with L1212 and L1214 sub-lines. Similarly, lines L911, L917 and L913 are all sub-lines of L9 and were not grouped together. This indicates that the sub-lines selected were phenotypically different from the original. Inbred lines N3 and L3233 were clustered together while SC and L5522 were in separate clusters. The observations are in agreement with the findings of Ristanovic et al. (1985), when L5522 was contaminated. The contamination had great impact

Table 7. Phenotypic Variation of maize inbred lines based on 12 qualitative traits.

No.	genotype	Intensity of silk colour	Intensity of internode Colour	Leaf attitude	Intensity of glum ring colour	Intensity ear sheath colour	intensity of tassel glume colour	Grain type	Tassel attitude of lateral branches	leaf colour	Hairiness of leaf margin	Intensity of leaf sheath colour	Ear shape
1	J185	1	1	1	1	1	1	1	3	7	3	1	2
2	K64-r	1	1	5	1	1	1	5	3	3	1	1	2
3	L12	3	1	3	1	1	1	3	3	5	3	1	2
4	L1212	1	1	3	1	1	1	4	3	7	1	1	3
5	L1214	5	1	5	1	1	1	5	3	7	3	1	3
6	L151	3	1	3	3	1	1	4	1	7	9	1	3
7	L152	3	3	5	7	1	1	3	1	7	5	1	2
8	L2	1	1	7	1	1	1	1	3	5	3	1	2
9	L211	1	1	5	1	1	1	1	5	5	3	1	1
10	L3233	1	1	5	1	1	1	4	3	3	3	1	3
11	L3234	1	1	1	1	1	1	5	5	5	1	1	1
12	L334	1	1	1	1	1	1	4	5	7	1	1	2
13	L5522	3	1	3	7	1	1	4	3	7	3	1	2
14	L911	1	5	7	7	3	1	1	1	7	5	1	1
15	L913	3	1	3	3	1	1	1	1	7	5	3	2
16	L917	3	1	5	1	1	3	2	1	7	3	1	2
17	N3	3	3	7	1	1	1	4	5	3	5	1	3
18	SC	3	1	5	1	1	1	5	3	5	3	1	2

on the phenotypic expression of the inbred line. This suggests that breeders should be using SC but not L5522 in their breeding works involving heterotic patterns. However, the line *per se* cannot be discarded as it may have other important attributes that can be used in breeding.

Shannon diversity index

Principal component and coordinate analysis

Principal coordinate (PCoA) of qualitative traits: The principal coordinate analysis of the qualitative traits resulted in the first axis explaining 42.0% of the variation, with an eigenvalue greater than 1. The second with eigenvalue less than 1, accounted for 15.6% of the total variation while the third and fourth axis accounted for 11.8 and 8.9% of the total variation respectively (Table 13). The sum of eigenvalues for axes1 and axes2 were 2.39. Four traits, namely leaf attitude, ear sheath colour, tassel glume colour and leaf sheath colour had high correlations (≤0.40) with the first axis. High correlations were also observed on tassel glume ring colour, grain type, attitude of tassel branches and leaf colour with the second axis. Leaf colour had the highest correlation (0.795) with the first axis and was fourth in the second axis. This implies that leaf colour was very important in discriminating genotypes.

The Shannon index, sometimes referred to as the Shannon-Weaver index is used to measure diversity. The index has been used to measure the phenotypic diversity for each trait (Shannon and Weaver, 1949). The Shannon Index for the 12 qualitative traits ranged from 1.09 to 1.24, with a mean of 1.20 and a range of 0.15 (Table 12). Leaf colour had the highest diversity index (1.24) and the intensity of tassel glume ring colour had the lowest (1.09). The diversity index for three traits, namely ear sheath colour, tassel glume colour,

Table 8. Contribution of each trait to clearly distinguish 18 inbreds.

Trait	Number of genotype pairs separated	Rank
Grain type	19	1
Intensity of internode colour	16	2
Intensity of glume ring colour	16	2
Leaf attitude	13	4
leaf colour	13	4
Tassel attitude of lateral branches	11	6
Intensity of Silk colour	10	7
Hairiness of leaf margin	9	8
Ear shape	8	9
Intensity ear sheath colour	0	10
intensity of tassel glume colour	0	10
Intensity of leaf sheath colour	0	10

Table 9. Variation of 18 maize inbred lines for 12 qualitative traits.

Trait	Category	Frequency	Relative frequency (%)
Intensity of silk colour	Absent/very weak	9.000	50.000
	Weak	8.000	44.444
	medium	1.000	5.556
Intensity internode color	Absent/very weak	15.000	83.333
	Medium	1.000	5.556
	Weak	2.000	11.111
Leaf attitude	Slightly recurved	5.000	27.778
	Strongly recurved	3.000	16.667
	Rectilinear	3.000	16.667
	Recurved	7.000	38.889
Intensity of glume ring colour	Absent/very weak	13.000	72.222
	Strong	3.000	16.667
	Weak	2.000	11.111
Intensity of ear sheath color	Absent/very weak	17.000	94.444
	Weak	1.000	5.556
intensity of tassel glume color	Absent/very weak	17.000	94.444
	Weak	1.000	5.556
Grain type	Dent	4.000	22.222
	Dent-like	6.000	33.333
	Flint	5.000	27.778
	Flint-like	1.000	5.556
	Intermediate	2.000	11.111
Attitude of tassel lateral branches	Rectilinear	5.000	27.778
	Recurved	4.000	22.222
	Slightly recurved	9.000	50.000

Table 9. Contd.

Leaf color	Dark green	10.000	55.556
	Light green	3.000	16.667
	Medium green	5.000	27.778
Hairiness of leaf margin	Absent/very weak	4.000	22.222
	Medium	4.000	22.222
	Very strong	1.000	5.556
	Weak	9.000	50.000
Intensity of leaf sheath color	Absent/very weak	17.000	94.444
	Weak	1.000	5.556
Ear shape	Conical	3.000	16.667
	Cylindrical	5.000	27.778
	Slightly conical	10.000	55.556

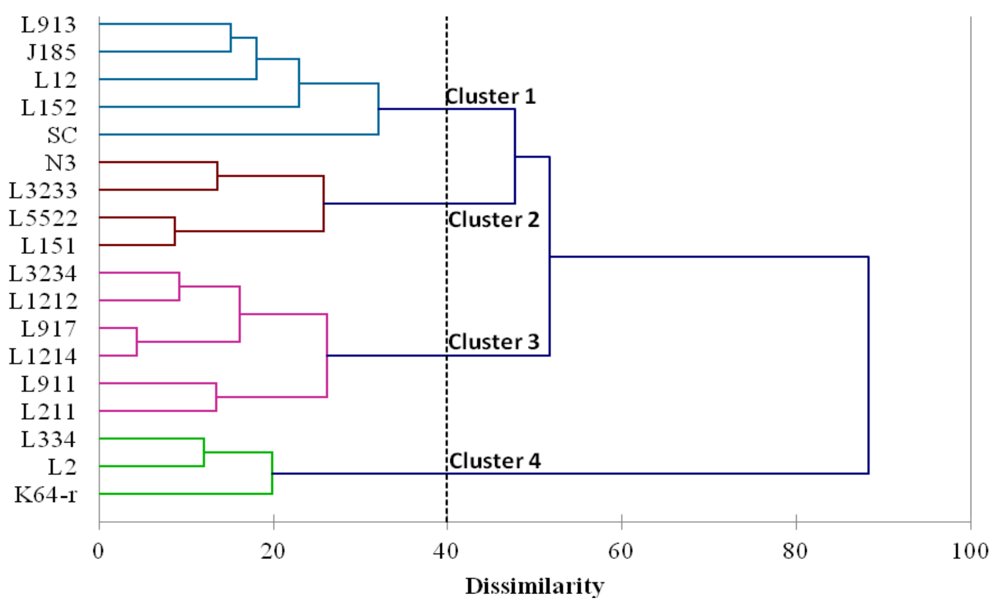

Figure 1. Dendrogram of maize inbred lines based on 24 morphological traits, using Euclidean distance matrix and Ward clustering method.

ear shape and leaf sheath colour was the same (1.23). On the other hand, the Shannon index for the 25 agronomic traits ranged from 0.95 to 1.26, with a mean of 1.24 and a range of 0.31 (Table 12). The highest index (1.26) was observed for days to silking (Dsilk), days to maturity, ear diameter (ED) and shelling percentage (%). The lowest index (0.95) was recorded in number of rotten cobs only. The Shannon index observed in this study was higher than that reported among maize accessions in Italy (0.789-0.849) and almost comparable to the result for Chinese germplasm (Li et al., 2002; Lucchin et al., 2003). Siopongco et al. (1999) considered a Shannon index of 0.68 and 0.80 to be medium and high degree of variation. In this study, a high degree of variation existed for all the traits studied. Furthermore, the quantitative traits were more diverse than qualitative traits. Similar findings have been reported in maize (Siopongco et al., 1999).

The high diversity index of LFA and PH could be used in the generation of heterotic hybrids. The results also indicate that there is wide diversity in the qualitative traits among the inbred lines used in the study. Therefore, these traits can be used in the development of identification keys. Traits that are known to be mildly

Table 10. Genetic dissimilarity of 18 maize inbred lines based on 12 qualitative traits.

	J185	**K64r**	**L12**	**L1212**	**L1214**	**L151**	**L152**	**L2**	**L211**	**L3233**	**L3234**	**L334**	**L5522**	**L911**	**L913**	**L917**	**N3**	**SC**
J185	0.00																	
K64r	7.21	0.00																
L12	4.00	4.47	0.00															
L1212	4.24	4.69	3.74	0.00														
L1214	7.00	6.08	4.12	5.00	0.00													
L151	7.87	9.90	7.07	8.72	7.28	0.00												
L152	8.49	9.17	7.48	8.37	7.55	6.48	0.00											
L2	6.32	5.29	4.90	5.83	6.40	8.83	8.00	0.00										
L211	5.00	5.39	4.12	5.39	6.63	9.00	8.54	3.00	0.00									
L3233	6.48	2.45	3.74	4.90	5.74	8.25	8.37	4.24	4.58	0.00								
L3234	5.39	5.00	4.58	4.12	6.93	10.05	10.05	7.81	6.00	5.74	0.00							
L334	4.12	6.08	4.58	3.00	6.48	9.64	9.64	7.55	5.83	6.40	2.45	0.00						
L5522	7.28	8.06	6.40	6.71	6.78	7.55	4.12	8.31	7.87	7.81	7.62	7.21	0.00					
L911	10.05	10.63	9.64	10.25	10.20	9.22	4.58	8.31	9.17	9.85	12.00	11.58	7.62	0.00				
L913	4.90	8.25	4.90	6.48	6.40	5.48	5.66	6.32	6.40	7.07	8.31	7.55	6.08	7.81	0.00			
L917	5.39	6.40	4.12	5.00	4.69	7.28	7.00	4.58	5.48	5.74	7.62	6.93	7.21	8.60	4.58	0.00		
N3	8.83	5.83	5.83	7.75	6.08	8.49	8.60	5.48	5.74	4.47	8.31	8.77	9.00	9.64	8.37	7.28	0.00	
SC	6.32	3.46	2.83	4.24	3.00	7.35	7.48	4.90	5.00	3.16	5.39	5.74	6.71	9.64	6.32	4.58	4.69	0.00

Table 11. Gower similarity coefficients based on 13 qualitative and 15 standardised quantitative traits for 18 maize inbred lines.

	J185	**K64-r**	**L12**	**L1212**	**L1214**	**L151**	**L152**	**L2**	**L211**	**L3233**	**L3234**	**L334**	**L5522**	**L911**	**L913**	**L917**	**N3**
J185																	
K64-r	9.46																
L12	7.17	8.31															
L1212	8.30	9.23	7.71														
L1214	9.65	9.71	8.43	7.35													
L151	11.82	13.49	10.25	10.20	10.47												
L152	10.45	12.10	9.99	10.90	9.60	9.83											
L2	9.83	8.67	10.02	10.24	9.82	13.73	12.24										
L211	8.25	8.98	6.78	7.84	8.75	11.49	10.54	9.56									
L3233	9.55	8.28	8.27	7.29	7.79	10.33	11.11	9.04	8.32								
L3234	8.75	8.66	9.00	5.96	8.30	12.49	12.06	11.27	8.23	8.57							
L334	7.35	7.85	9.31	8.53	10.19	13.51	12.65	9.01	9.42	10.35	8.06						
L5522	10.22	11.67	9.03	8.52	9.30	8.62	7.60	12.62	10.22	9.58	10.41	11.60					

Table 11. Contd.

L911	12.61	13.38	11.52	12.02	12.00	12.17	9.11	11.64	10.53	12.47	13.70	14.06	10.70				
L913	7.37	10.82	7.60	7.95	8.70	7.68	8.71	9.68	8.77	8.97	10.24	9.93	8.04	9.79			
L917	8.54	9.63	7.90	7.00	5.54	10.42	9.65	9.47	7.06	8.10	8.71	10.59	9.49	10.23	7.74		
N3	11.66	11.52	9.26	9.50	9.01	10.86	11.70	10.70	9.20	6.86	11.04	13.11	10.62	11.65	10.31	9.50	
SC	10.42	9.03	8.13	8.95	8.74	10.47	10.34	9.53	8.95	8.11	10.06	9.00	10.53	12.95	8.86	9.79	9.66

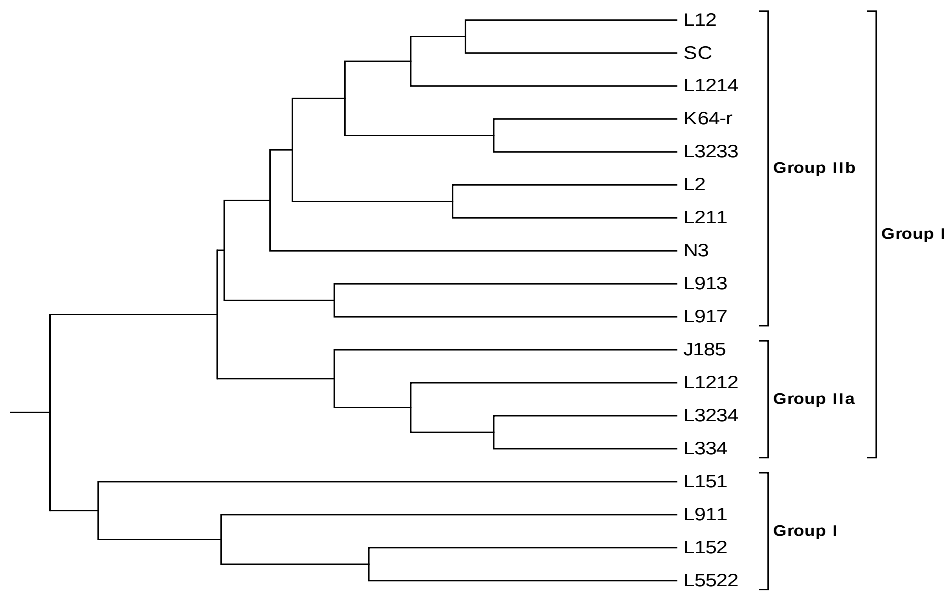

Figure 2. Dendrogram of maize inbred lines based on 12 qualitative traits, using Gower similarity matrix and UPGMA clustering method.

influenced by environment are effective in variety discrimination (Dillmann and Guerin, 1998) and these should be used in developing variety identification keys. Polygenic traits, like kernel type, ear height, earliness are some of the traits reported to be mildly affected by environment (Dillmann and Guerin, 1998).

Principal component analysis (PCA) of quantitative traits

The principal component analysis of the quantitative traits resulted in the first seven components explaining 84.6% of the total variation, with eigenvalues greater than 1. The first component accounted for 27.5% of the total variation. The second and third components accounted for 15.2% and 12.2% of the total variation respectively (Table 14). Cumulatively, the first and second components explained 42.6% of the total variation.

Grain yield had the highest positive loading

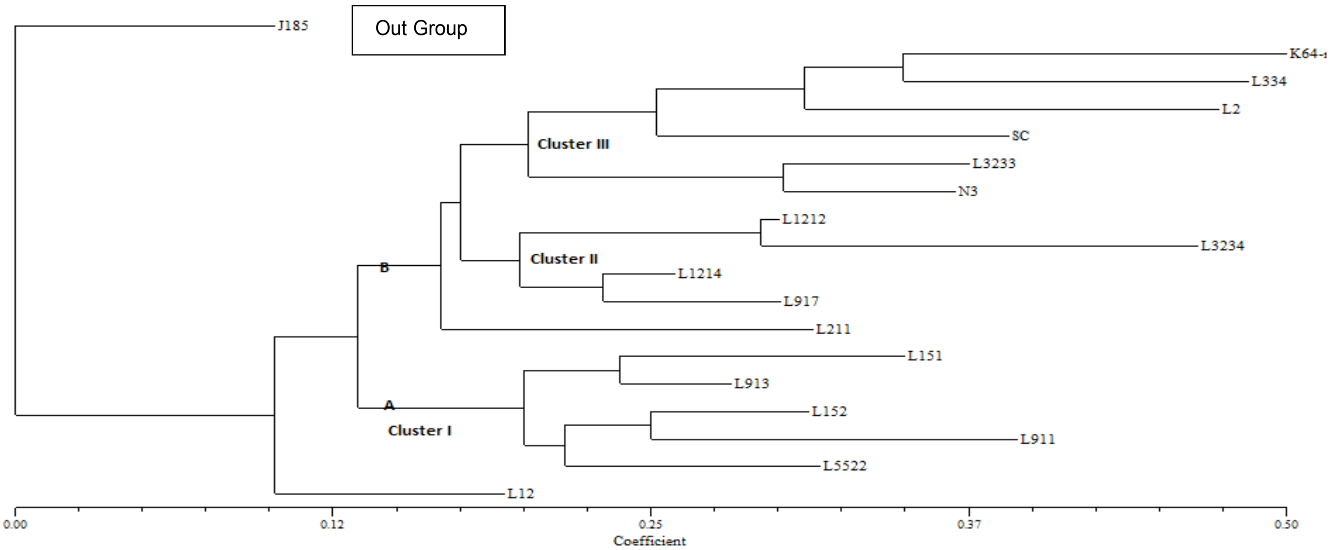

Figure 3. Dendrogram of Maize inbred lines based on 25 quantitative and 12 qualitative traits, using Neighbour Joining clustering method.

Table 12. Diversity Index for 12 qualitative traits for 18 inbred lines.

Quantitative traits					
Trait	**Diversity index**	**Evenness**	**Sample**	**Diversity index**	**Evenness**
Dsilk	1.26	1.00	Intensity of Silk colour	1.19	0.95
maturity	1.26	1.00	Intensity of internode Color	1.17	0.93
PH	1.25	1.00	Leaf attitude	1.20	0.96
EH	1.24	0.99	Intensity of glum ring colour	1.09	0.87
PH to EH ratio	1.25	1.00	Intensity of ear sheath color	1.23	0.98
rotten cob No	0.95	0.88	Intensity of tassel glume color	1.23	0.98
TaxisUpperB	1.25	0.99	Grain type	1.20	0.95
LfW	1.25	1.00	Attitude of tassel lateral branches	1.20	0.96
LfL	1.25	0.99	Leaf color	1.24	0.99
LfA	1.24	0.99	Hairines of leaf margin	1.19	0.95
EL	1.25	1.00	Intensity of leaf sheath color	1.23	0.98
ED	1.26	1.00	Ear shape	1.23	0.98
HSWT g	1.24	0.99	Mean	1.20	0.96
GY kgha	1.25	0.99	Max	1.24	0.99
GLS	1.24	0.99	Min	1.09	0.87
GRNo	1.25	1.00	Range	0.15	0.12
ERNo	1.25	1.00			
shelling %	1.26	1.00			
TBNo	1.24	0.99			
TL long	1.25	1.00			
TUBL short	1.25	1.00			
TL short	1.22	0.97			
6cm Lower	1.25	1.00			
6cm Upper	1.25	1.00			
TaxisBelowB	1.25	1.00	**Index for combined (qualitative and quantitative traits)**		
Mean	1.24	0.99	Mean	1.24	0.99
Max	1.26	1.00	Max	1.26	1.00
Min	0.95	0.88	Min	0.95	0.87
Range	0.31	0.12	Range	0.31	0.13

Table 13. Principal coordinate analysis of 12 qualitative traits.

	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6	Axis 7	Axis 8
Eigenvalues	1.743	0.647	0.489	0.371	0.285	0.18	0.164	0.127
Percentage	42.072	15.613	11.794	8.952	6.866	4.347	3.949	3.062
Cumulative percentage	42.072	57.685	69.479	78.431	85.296	89.643	93.592	96.654
PCO case scores								
Intensity of Silk colour	-0.099	-0.062	-0.146	-0.004	-0.273	0.072	-0.162	0.178
Intensity of internode Color	-0.352	0.092	0.017	-0.024	0.055	-0.082	-0.004	-0.158
Leaf attitude	0.456	0.051	-0.454	-0.221	0.244	0.073	-0.012	0.004
Intensity of glum ring colour	-0.227	0.383	0.018	-0.125	-0.054	-0.135	0.228	0.143
Intensity of ear sheath color	-0.423	0.031	0.094	-0.023	0.122	-0.017	-0.050	-0.068
Intensity of tassel glume color	-0.410	-0.020	0.081	-0.018	0.058	0.070	-0.128	-0.021
Grain type	0.290	-0.394	0.067	-0.286	-0.192	-0.174	0.004	-0.084
Attitude of tassel lateral branches	0.275	-0.377	0.174	0.224	0.240	-0.087	0.048	0.143
Leaf color	0.795	0.353	0.362	-0.007	-0.034	0.096	-0.067	-0.033
Hairiness of leaf margin	0.179	0.137	-0.269	0.405	-0.113	-0.137	-0.029	-0.084
Intensity of leaf sheath color	-0.418	0.015	0.079	-0.016	0.064	0.057	-0.062	0.055
Ear shape	-0.066	-0.208	-0.022	0.094	-0.117	0.265	0.234	-0.076

Table 14. Principal component analysis of 25 quantitative traits.

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Eigenvalue	6.867	3.789	3.045	2.365	2.069	1.878	1.134	0.992	0.743	0.565
Proportion	0.275	0.152	0.122	0.095	0.083	0.075	0.045	0.040	0.030	0.023
Cumulative	0.275	0.426	0.548	0.643	0.725	0.800	0.846	0.886	0.915	0.938
Variable					**PCA scores**					
Dsilk	0.216	-0.286	0.075	-0.021	-0.147	-0.275	-0.024	0.077	0.085	0.103
maturity	0.278	-0.123	0.001	-0.061	0.054	-0.058	-0.494	0.054	0.167	-0.278
PH	0.235	-0.010	-0.113	0.049	-0.374	-0.210	0.060	-0.141	0.395	0.279
EH	0.313	-0.080	-0.111	0.016	-0.228	0.060	0.122	0.291	0.134	-0.034
PH to EH ratio	-0.253	0.063	0.114	-0.019	0.160	-0.153	-0.255	-0.521	-0.044	0.218
rotten cob No	-0.235	-0.217	-0.124	0.104	-0.087	0.085	0.125	0.071	0.377	-0.321
TaxisUpperB	0.056	0.039	0.494	0.229	0.063	-0.023	-0.153	0.055	0.209	0.028
LfW	0.248	0.160	-0.001	0.099	0.227	0.305	-0.301	0.156	0.058	-0.011
LfL	0.221	0.107	-0.192	0.334	0.070	0.185	0.207	-0.164	-0.116	0.332
LfA	0.272	0.126	-0.130	0.278	0.138	0.255	-0.038	-0.052	-0.035	0.167
EL	0.203	-0.306	-0.070	-0.242	0.225	0.062	-0.016	0.037	-0.238	0.219
ED	0.157	0.129	0.129	0.006	-0.449	0.256	-0.009	-0.264	-0.269	-0.244
HSWT g	0.243	-0.275	-0.050	-0.108	-0.138	-0.140	0.092	-0.250	-0.179	-0.134
GY kgha	0.276	0.204	-0.103	-0.226	-0.128	0.197	-0.102	-0.006	0.063	0.015
GLS	0.008	-0.007	-0.206	0.472	0.144	-0.143	0.195	0.123	-0.068	-0.211
GRNo	-0.040	-0.015	-0.266	-0.390	0.335	0.132	0.224	0.032	0.200	-0.107
ERNo	-0.216	0.166	0.126	-0.054	-0.130	0.333	-0.205	0.253	0.124	0.067
shelling %	-0.012	0.426	-0.089	0.094	0.037	-0.078	0.242	-0.206	0.231	-0.167
TBNo	0.083	0.344	-0.080	-0.069	-0.036	-0.420	-0.179	0.177	-0.242	-0.044
TL long	0.089	0.249	0.265	-0.326	-0.008	-0.051	0.276	0.043	0.284	0.324
TUBL short	0.113	0.155	0.374	-0.167	-0.009	0.072	0.369	0.123	-0.320	-0.269
TL short	0.020	0.346	-0.207	-0.030	0.014	-0.390	-0.104	0.271	-0.090	-0.009
6cm Lower	0.258	-0.050	0.120	-0.064	0.431	-0.095	0.114	0.001	0.047	-0.024
6cm Upper	0.257	0.112	0.102	-0.022	0.187	-0.073	-0.043	-0.383	0.233	-0.383
TaxisBelowB	0.079	-0.124	0.434	0.278	0.095	-0.129	0.144	0.168	0.027	0.057

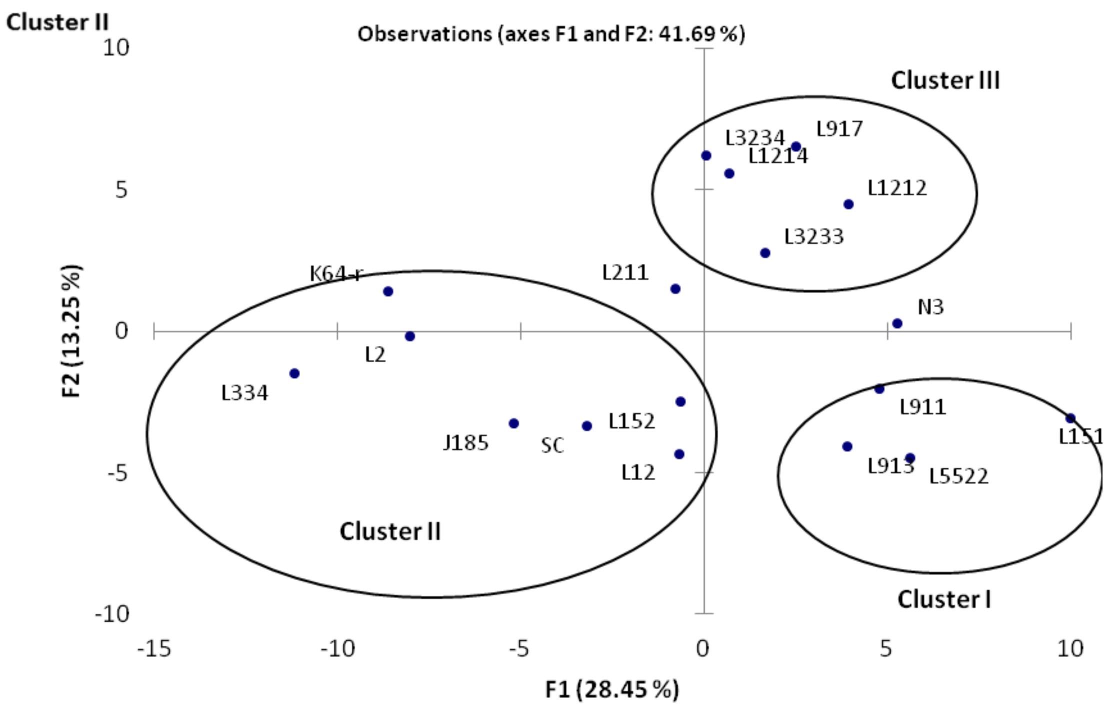

Figure 4. Scatter plot of the maize inbred lines based on 37 traits.

(0.276) in the first while shelling % and TaxisUpperB had the highest positive loadings in components 2 (0.346) and 3 (0.494), respectively (Table 14). TaxisUpperB, ED, TL long, TUBL short and 6 cm upper had positive loadings in the first three components, while Lfw, LfL, LfA, GYkgha, TBNo and TL short had positive loadings in the first two components. These traits were important for discriminating the maize inbred lines.

Principal component analysis for quantitative and qualitative traits

When the quantitative traits were converted to categorical data and combined with qualitative data, the first fourteen components explained 97.97% of the total variation, with eigenvalues greater than 1. The first component accounted for 28.5% of the total variation. The second and third components accounted for 13.3 and 10.3% of the total variation respectively (Table 15). Cumulatively, the first and second components explained 41.7% of the total variation.

The PCA grouped genotypes that were similar to that produced by the neighbour joining clustering method (Figure 4). Inbred lines L3233, L152 and SC were grouped differently by both methods. The trait, LfA had the highest factor loading (2.41) in the first component followed by EH (2.06) and GY (2.02) (Table 15). The axis is considered productivity and yield axis since it loaded highly for yield and reproductive traits. GY had the highest positive loadings in component 2 (1.63) and component 3 (1.38) respectively (Table 15). GY had the second highest factor loading in the first component. The PCA indicates that ED, 6 cm Upper, PH, TBNo, GY and leaf attitude were important in distinguishing inbreds. Out of these, TL long, GY and TBNo had positive loadings in the first three components. GY was the most important trait as it loaded positively and highly with the first and second factors (2.02 and 1.63 respectively). The inbreds, based on the PCA scores, were divided in 3 clusters (Figure 4).

PCA (Figure 4) and cluster analysis (Figure 3) grouped some inbred lines similarly for cluster I and cluster III. The lines in II and IV (Figure 1) were grouped in cluster II by PCA. This resulted in Cluster II having sub-clusters. The differences in the classification of the inbred lines could be attributed to the differences in data used for quantitative traits (code or standardised). However, the study demonstrates that either of the method could be used to provide information about the diversity of maize.

Comparison of dissimilarity matrix derived from qualitative and quantitative traits

The Mantel test statistic (Z) were calculated to measure the degree of relationship between the dissimilarity matrixes generated from qualitative, quantitative and combined data. The p-value was calculated using the distribution of r (AB) estimated from 10,000 permutations.

Table 15. Principal component analysis of 18 maize inbred lines across 37 traits.

Varibles	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
Eigen value	29.19	13.59	10.6	9.01	8.38	6.13	5.23	4.63	3.77	3.26	2.25	1.98	1.32	1.18
Var (%)	28.45	13.25	10.33	8.78	8.17	5.97	5.1	4.51	3.68	3.18	2.19	1.93	1.29	1.15
Cum %	28.45	41.69	52.02	60.81	68.98	74.95	80.05	84.56	88.24	91.42	93.61	95.53	96.82	97.97
factor loadings*														
DSilking	0.53	-0.41	0.38	-0.74	0.34	0.27	0.04	-0.21	-0.19	0.24	-0.05	-0.48	-0.27	0.02
PH to EH ratio	-0.84	0.13	-0.05	0.25	-0.06	0.01	0.06	0.05	0.01	0.25	0.05	0.17	-0.27	0.01
RottenCob	-0.97	-0.25	-0.67	-0.68	0.00	0.19	0.47	-0.04	0.33	-0.38	0.78	-0.18	0.29	-0.01
LfW	0.55	-0.34	-0.06	0.74	-0.32	0.06	0.23	0.17	-0.12	0.1	-0.03	0.33	0.09	-0.19
EL	0.87	-0.67	-0.23	-0.27	-0.59	-0.44	-0.68	-0.04	-0.22	0.08	0.04	-0.2	-0.32	0.20
ED	0.71	0.65	0.13	-0.11	0.06	-0.47	0.52	-0.32	0.07	0.05	-0.36	-0.16	0.16	0.09
HSWTg	0.52	-0.15	-0.10	-0.57	-0.14	-0.03	-0.07	0.03	0.15	0.27	-0.30	-0.09	-0.25	-0.15
GLS	0.15	-0.35	-0.69	0.08	0.33	0.09	-0.23	-0.10	-0.21	-0.31	-0.11	0.36	0.11	0.09
GRNo	-0.33	0.41	-0.12	0.27	-0.23	-0.32	-0.69	-0.31	-0.34	0.04	0.15	-0.11	0.19	0.10
ERNo	-0.34	0.50	-0.23	0.56	0.21	-0.71	0.76	-0.33	0.06	-0.18	0.11	0.44	-0.03	0.25
shelling %	-0.31	1.25	-0.06	0.52	0.5	0.27	0.14	-0.14	-0.39	0.21	0.31	-0.11	-0.02	-0.22
TUBL short	0.13	0.10	1.30	0.40	0.14	0.46	-0.34	-0.52	0.24	-0.47	-0.33	-0.03	0.21	0.03
TL short	-0.24	0.90	0.20	0.24	0.52	-0.06	-0.28	0.62	0.04	0.08	0.15	-0.22	0.17	-0.23
6 cm Lower	0.77	-0.32	0.03	0.15	-0.43	0.69	-0.45	0.33	-0.16	-0.33	0.35	0.17	-0.11	-0.06
6 cm Upper	0.50	0.47	-0.04	0.44	-0.50	0.64	0.38	0.60	-0.44	-0.5	-0.35	-0.09	0.19	0.43
TaxisBelowB	0.25	-0.68	0.50	0.26	-0.07	0.54	0.3	-0.15	0.15	0.11	0.07	-0.13	0.15	-0.20
Maturity	1.43	-0.21	0.41	-0.26	-0.67	-0.12	0.08	0.57	-0.61	0.47	0.42	0.08	0.14	0.25
TaxisUpperB	0.22	-0.88	0.72	0.70	-0.03	0.8	0.66	-0.24	-0.14	0.54	0.02	0.13	-0.03	0.01
TBNo	0.04	0.87	0.51	0.27	0.71	-0.15	-0.25	1.18	-0.07	-0.07	-0.15	0.08	-0.20	-0.03
TL long	0.19	1.27	1.38	-0.13	-0.47	0.70	-0.30	-0.48	0.30	0.00	0.32	0.05	-0.16	0.12
PH	1.49	0.55	-0.20	-1.19	0.76	0.56	0.67	0.26	0.34	0.25	0.04	0.28	-0.14	0.15
EH	2.06	-0.27	-0.10	-0.76	0.27	0.03	0.3	-0.03	-0.21	-0.51	-0.08	-0.30	0.20	-0.05
LfL	1.59	0.30	-1.13	0.65	0.36	0.33	-0.32	-0.29	0.52	0.02	-0.28	-0.07	-0.18	-0.04
LfA	2.41	0.02	-0.92	1.20	-0.28	0.21	0.07	-0.06	0.21	-0.21	0.33	-0.15	-0.13	-0.13
GY kgha	2.02	1.63	0.33	-0.14	-0.56	-0.72	0.08	-0.37	-0.1	0.23	0.07	0.02	0.13	-0.12
Silk colour	0.50	-0.12	0.29	-0.43	0.12	0.34	-0.44	0.27	0.27	-0.30	-0.09	0.43	0.00	-0.08
Internode Color	0.29	-0.19	0.22	0.24	0.67	-0.15	0.31	0.06	-0.38	0.10	0.13	0.19	-0.16	-0.17
Leaf attitude	0.25	0.20	-0.14	-0.03	1.65	0.24	-0.48	-0.36	-0.52	-0.10	0.24	-0.08	0.09	0.15
Int GlumRing	0.89	-1.03	1.16	0.32	0.49	-0.78	0.26	-0.15	-0.42	-0.63	0.12	-0.05	-0.25	-0.11
Ear shth Color	0.10	-0.06	0.01	0.16	0.28	-0.12	0.2	-0.05	0.02	0.00	0.01	0.02	-0.10	-0.12
TassGlum Color	0.05	0.20	0.05	0.07	0.07	0.04	-0.07	0.08	0.18	-0.11	-0.07	0.04	0.05	0.21
Grain type	0.01	0.42	-0.11	-0.92	-0.55	0.04	0.00	-0.33	-0.39	-0.47	-0.09	0.59	-0.08	-0.38
TLatBrchAttitude	-0.56	0.35	-0.43	-0.10	-0.4	0.42	0.32	0.17	-0.64	0.02	-0.42	-0.29	0.11	-0.39
leaf color	0.33	-0.26	0.67	0.10	-0.13	-0.58	0.18	0.62	0.82	-0.23	0.12	-0.19	0.12	-0.18
Lf Hairiness	1.22	-0.85	0.17	-0.06	0.49	-0.2	-0.51	-0.02	0.11	0.63	-0.13	0.34	0.57	-0.08
Int.Lf shthC	0.08	-0.12	-0.10	0.07	-0.04	-0.13	-0.06	0.03	0.12	0.08	0.00	0.05	-0.14	0.16
ear shape	0.18	0.07	-0.17	-0.21	-0.14	0.04	-0.42	0.03	-0.02	-0.01	0.26	0.09	0.03	-0.16

*All quantitative traits were coded according to the instructions shown in Table 1.

The matrix correlation between qualitative and quantitative was low (r=0.048) and non-significant. However, the correlations of qualitative and quantitative traits with combined data were high and highly significant (r=0.82 and r=0.61, respectively). There was an agreement of 82% between qualitative and quantitative matrices using the Mantel matrix correspondence test. On the other hand the quantitative traits were 61% in agreement with the combined data.

The low correlation between the qualitative and quantitative could be attributed to the different methods used in calculating the dissimilarity matrices, because each of the dissimilarity matrix has different mathematical properties (Mohammadi and Prasanna, 2003). Since the correlations for association to mixed data by qualitative and quantitative are high, while their correlations between them is low, suggests the need for combining the two data sets for analysis. Hence qualitative and quantitative data should be used for assessing genetic diversity in combination.

Conclusions

The study assessed the pattern and extent of the phenotypic diversity of elite inbred lines. The results reveal that phenotypic selection for the creation of sub-lines and inbred line recycling significantly affected the morphological diversity of inbred lines. This diversity can be exploited for the generation of heterotic hybrids. The observed disparity between clustering and the expected similarity could be attributed to mutation and /or admixtures. Admixtures could have occurred at the time when there was high staff turn-over coupled with reduced government funding to research activities.

Abbreviations: AREX, Department of Agriculture and Rural Extension; **CIMMYT,** International Maize and Wheat Improvement Centre; **DUS,** distinctness, uniformity and stability; **SCCI,** Department Seed Control and Certification Institute; **UPOV,** International Union for the Protection of New Varieties of Plants; **ZARI,** Zambia Agriculture Research Institute.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Response of wild type sorghum (*Sorghum bicolor* (L.) Moench) accessions to pre- flowering drought stress

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A study was conducted to evaluate the response of eleven wild type sorghum accessions to pre-flowering moisture stress. The experiment was carried out at Jimma University College of Agriculture and Veterinary Medicine research site under greenhouse condition in 2013/2014 cropping season. A randomized complete blocks design with two replications was used. The experiment was irrigated by a movable tubular irrigation system the whole season. Pre- flowering drought stress was induced by totally withholding irrigation from panicle differentiation to flowering. A total of 11 morphological characters putatively related with crop performance under drought were studied. Significant variation was found for leaf rolling, root length, leaf drying, plant height and flag leaf width; however, the remaining traits showed non-significant difference among treatments due to moisture stress at (p≤0.05). Based on this finding, accessions TS217 and DA119 collected from Tigray and Amhara region respectively are found to have superior pre-flowering drought tolerance followed by accessionTS211compared with the check B35. Hence; the authors recommend using accession DA119 and TS217 as parent materials during improvement of sorghum for drought tolerance. However, since this result is limited to data collected in one year in one location and does not compare yields, including other locally adapted lines and doing the experiment over locations and seasons is advisable.

Key words: Sorghum, drought, accession, pre-flowering, selection.

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the most important cereal crops widely grown for food, feed, fodder, forage and fuel in the semi-arid tropics of Asia, Africa, the Americas and Australia. It is an essential to diets of poor people in the semi-arid tropics where droughts cause frequent failures of other crops. It contributes to the food security of many of the world's poorest, most food-insecure agro-ecological zones including Ethiopia (FAO and ICRISAT, 1996). In the year 2012, sorghum was grown worldwide on 43,727,353 ha with an output of 61.7 million tons (FAO, 2012). The world average yield is 1314 kg/ha; the yield from developed countries is 3056 kg/ha and from developing countries is 1127 kg/ha. Despite the low productivity in developing countries, it account for 90% of the area and 77% of the total output produced. In Ethiopia, sorghum is

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the fourth important cereal after tef, wheat and maize; and was grown on 1,253,620 ha with a national average yield of 500 to 900 kg/ha (CSA, 2012).

Ethiopia is the original home of sorghum and is the source of many wild and cultivated forms adapted to a wide range of growing conditions (Doggett, 1988; Vavilov, 1951; Harlan and Wet, 1971, 1972). Sorghum exists in tremendous variability throughout the areas of sorghum production in Ethiopia. Many sorghum growing areas contain pockets of isolation; consequently such places contain a large amount of genetic variability which is valuable to sorghum breeding and improvement in Ethiopia and the world at large. Such genetic variability would, of course, be very essential in the world sorghum collection (Kebede et al., 1991).

On the other hand, in Ethiopia sorghum is usually grown in areas where droughts cause frequent failures of other crops and difficult to grow other food crops and feed grains. Its ability to adapt to such challenging situations makes sorghum an important food and feed crop in the arid and semi-arid regions of the world including Ethiopia (FAO and ICRISAT, 1996; Crasta et al., 1999). Its remarkable ability to produce grains under adverse conditions makes sorghum an important “fail-safe” source of food, feed and fuel.

However; the yield of sorghum is affected by a wide array of biotic and abiotic stresses. These are; drought, shoot fly, stem borer, midge, grain mold and striga that together cause an estimated total yield loss to the tune of US$ 3032 million (Blum, 2004). Nevertheless, drought stress is one of the major agronomic problems that limit the attainment of maximum yield more than any other environmental parameter, with special reference to the arid and semi-arid regions (Krieng, 1975; Tuinstra et al., 1997; Abdula et al., 2004). Wenzel (1999) also reported that drought stress is more problematic to small-scale farmers (resource-poor farmers) as their farming activities depend solely on rainfall without option of irrigation as in the case of Ethiopia.

Sorghum tolerates and avoids drought more than many other cereal crops, but the drought response of sorghum does not come without a yield loss. Water stress at the vegetative stage alone can reduce yield more than 36%, and water stress at the reproductive stage can reduce yield more than 55% (Tuinstra et al., 1997). Eighty percent of sorghum production in the world is under dry land conditions.

For the last half century variety development for lowland parts of Ethiopia has focused on the selection of early maturing varieties that can escape drought. A number of early sorghum open pollinated varieties were developed and released for these areas (Asfaw et al, 2007). There are, however, disadvantages to early maturity. Cultivars that mature extremely early tend to be lower in yield because the plants have a shorter growth period to flower and store nutrients in the grain (Sleper and Poehlman, 2003). Recently new genetic tools and more powerful statistical analyses provide an alternative approach to enhance genetic improvements through the identification of molecular markers linked to genomic regions or QTLs controlling quantitative traits. However, the use of naturally available germplasm has no replacement.

Ethiopia is the original home of sorghum; it is therefore, reasonable to assume that the country may have valuable wild germplasm which can be used for sorghum improvement to drought. Even though considerable work has been done on plant response to moisture stress (Tuinstra et al., 1996; Xu et al., 2000; Kebede et al., 2001; Haussmann et al., 2002), there has been little information about the performance of Ethiopian wild sorghum genotypes to drought. Therefore; the objective of this study was to evaluate the response of wild sorghum accessions collected from different parts of Ethiopia to pre-flowering drought stress, and to identify the genotypes which have more tolerance to drought stress at pre-flowering stage.

MATERIALS AND METHODS

Experimental site

The experiment was conducted under greenhouse condition at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) research field in the year 2014/2013. JUCAVM is geographically located at about 7°, 33° N latitude and 36°, 570 E longitude at an altitude of 1710 meters above sea level. The mean maximum and minimum temperatures are 26.8 and 11.4°C respectively, and the mean maximum and minimum relative humidity are 91.4 and 31.2% respectively. The annual rainfall of the area is 1500 mm.

Experimental materials

Wild sorghum accessions collected from different parts of Ethiopia used in the study are given in Table 1.

Experimental design and method of analysis

A randomized complete blocking design was used. Eleven accessions and one released verity (B35) was used for the study. B35 is highly susceptible to pre-flowering drought stress, so that it was considered as a negative control. Each pot had 7 plants. At planting, 22.4 kg/ha of N and 44.8 kg/ha of K was applied. After 2 weeks, the pots were thinned to 5 plants/pot. An additional 89.7 kg/ha of urea were applied to all treatments when the plants were 5 weeks old. Three plants were selected from each treatment for recording different morphological traits. The experiment was irrigated by a movable tubular irrigation system the whole season. However; pre-flowering drought stress was induced by totally withholding irrigation from panicle differentiation to flowering.

Data were collected from three randomly selected plants for the following traits: Leaf rolling plant height; flag leaf length, flag leaf width, root length, dry shoot weight, dry root length, fresh root weight, leaf drying and No. of tillers. The collected data were subjected to analysis of variance as per Gomez and Gomez (1984) and least significant difference (LSD) was used to separate the means both at 1 and 5% probability level.

Table 1. Wild sorghum accessions collected from different parts of Ethiopia in 2013.

AC. NO	Region	Zone	District	Latitude	Longtude	Altitude	Status
DW111	Amhara	Kemise	Dawachefa	10°80'N	39°83'E	1476	Wild
SE312	SNNP	Guragie	Sertie	8°26'N	37°60'E	1412	Wild
SO320	Oromia	Jimma	Sokoru	8°23'N	37°57'E	1148	Wild
AT85	Amhara	North Shewa	Ataye	10°38'N	39°93'E	1475	Wild
SO324	Oromia	Jimma	Sokoru	8°08'N	37°45'E	1950	Wild
DA119	Amhara	Kemise	Dawachefa	10°96'N	39°77'E	1597	Wild
TS207	Tigraye	North West	Tselemti	13°63'N	38°15'E	1352	Wild
TS217	Tigraye	North West	Tselemti	13°63'N	38°15'E	1352	Wild
KE274	Amhara	South G.	Kemkem	12°16'N	37°72'E	2003	Wild
TS211	Tigraye	North West	Tselemti	13°63'N	38°15'E	1352	Wild
SO326	Oromia	Jimma	Sokoru	8°08'N	37°45'E	1950	Wild
B35	Jimma	Jimma	-	-	-	-	Released

Table 2. Analysis of variance for ten traits considered in the study in 2014/2013.

Traits	DF	SS	MS	CV
Root length (RL)	10	456.08	45.61**	12.53
Flag leaf width (FLW)	10	7.47	0.75*	12.33
Flag leaf length(FLL)	10	522.4	52.24ns	12.6
Plant height (PH)	10	1510.66	151.07 *	8.6
Leaf rolling (LR)	10	5.09	0.51**	15.46
Leaf dried (LD)	10	619.3	61.93**	13.75
No. tillers (NT)	10	13	1.3 ns	34.36
Dry root weight (DRW)	10	0.0005560	0.0000556^{ns}	8.19
Fresh root weight (FRW)	10	0.0218984	0.0021898^{ns}	7.0
Dry shoot weight (DSW)	10	0.0512	0.00512	10.23

DF, Degree of freedom; SS, sum of square; MS, mean square; CV, coefficient of variation in %.

RESULTS AND DISCUSSION

Analysis of variance

From the analysis of variance, plant height, flag leaf length, dry shoot weight, dry root length, fresh root weight and number of tillers per plant showed non-significant difference among treatments at P≤0.05 probability level. Whereas, leaf rolling, root length, leaf drying, plant height and flag leaf width showed significant difference among treatments at P≤0.05 probability level (Table 2). This indicated the presence of a considerable amount of genetic variability for leaf rolling, plant height, root length, leaf drying, flag leaf width among the accessions considered in the study due to moisture stress.

Shoot related traits

The analysis of variance for plant height, flag leaf width, leaf rolling and number of leaf dried showed that there is significant difference between accessions due to moisture stress (Table 2). According to Purseglove (1972), the height of sorghum plant ranges from 0.5 to 6 m tall depending on variety and growing conditions. In this study, accession TS217 collected from Tigray region showed the shortest plant height (93.75 cm) whereas; accession (AT85) from Amhara region had the maximum plant height (123 cm) (Table 3). Tuberosa (2003) also reported differential responses of genotypes to variable soil moisture deficits for their specific shoot and root lengths. According to Tuinstra (1996), plants are able to produce flowers with a minimum vegetative growth, which enables them to produce grains with a limited water supply; this mechanism could be considered as one mechanism of escaping drought in sorghum.

Accessions also showed different response for water stress in flag leaf width (FLW) (Table 2). The widest flag leaf width (6.41) is observed from accession DA119 and the narrow FLW is observed from accession TS217 followed by TS211 which is close to B35 (7.7) (Table 3). During moisture stress plants usually reduce their leaf

Table 3. The mean value of accessions collected from different parts of Ethiopia in 2014/2013.

S/N	Acc. No.	PH	FLW	LD	LR	RL
1	DW111	110.00	5.965	50.5	4	50
2	SE312	114.33	5.135	39.5	4	50.34
3	SO320	119.1	6.050	56	4	54.17
4	AT85	123.50	5.635	49	3.5	47.16
5	SO324	109.00	5.915	50	4	53.5
6	DA119	111.41	6.415	39.5	5	56.5
7	TS207	104.75	4.900	50.5	4	60.34
8	TS217	93.75	4.515	44	5	58.83
9	KE274	101.83	5.000	56	4.5	52.66
10	TS211	120.75	4.800	49	3.5	49.16
11	SO326	111.66	5.250	46	4.5	45
12	B35	113.00	7.7	62	4	52
LSD		5.5	1.354	4.3	0.25	3.4

RL; Root length; FLW, flag leaf width; PH, plant height; LR, leaf rolling; LD, leaf dry.

Table 4. Correlation coefficient among traits for the 11 sorghum accessions used in the study

RL	FLW	FLL	PH	LR	LD	NT	DSW	DRW
FLW	-0.099							
FLL	-0.170	0.274						
PH	-0.370	0.307	0.177					
LR	0.235	-0.347	0.046	0.081				
LD	0.146	0.017	0.200	-0.067	0.028			
NT	-0.303	0.009	-0.292	0.306	-0.303	-0.569		
DSW	-0.065	-0.069	-0.386	0.173	-0.120	0.122	0.019	
DRW	-0.123	0.223	-0.260	0.330	-0.005	-0.058	0.037	0.568**
FRW	0.103	-0.259	-0.163	0.009	-0.132	-0.035	0.160	-0.027

RL, Root length; FLW, flag leaf width; FLL , flag leaf length; PH , plant height; LR , leaf rolling; LD, leaf dried; NT, number of tillers; DSW, dry shoot weight; DRW; dry, root weight; DFW, dry fresh weight.

area to limit transpiration, hence, accessions which showed narrow leaf width had better drought resistance than others. This result agrees with Passioura (1996) who reported that plants reduce their leaf area to limit transpiration during moisture stress.

The analysis of variance for leaf rolling showed that there was significant difference between sorghum accessions due to drought or water stress (Table 2). As compared to B35, the maximum leaf rolling (5 score) was recorded from accession TS217 and DA119. However, accession AT85 and TS211 showed minimum leaf rolling score (3.5) (Table 3). In principle, the stomatal resistance of the upper and lower leaf surfaces differed in response to water stress. When the upper leaf surface is rolled inside tissues lose turgor, the upper surface stomata may be responding to a modified microclimate with less incident solar radiation, lower evaporative demand, and possibly lower CO_2 concentration which in turn reduce the rate of evaporation. This implies that the accession which had maximum leaf rolling could be exploited as parent for improvement of drought tolerance in sorghum.

In addition, the highest number of leaves dried was recorded from accession B35, KE274 and SO320 followed by DE111 and TS207 (Table 3). However, low number of dried leaf was recorded from accession SE312 and TS217 followed by SO326. This indicated that the less dried accessions SE312, TS217 and SO326 had better resistance to moisture stress than others.

Root length

The analysis of variance for root length showed that there is significant difference between accessions due to moisture stress (Table 2).The maximum root length was recorded from accession TS217 and DA119 whereas; the shortest root length was recorded from accession SO326 and AT85 (Table 3). Water stress at different stages might lead to higher dry root weights, longer roots, coleoptiles and higher root/shoot ratios which could be exploited as selection criteria for stress tolerance in crop plants at very early stage of growth (Chaves et al., 2003). Thus, those accessions which showed maximum root length could be considered for improvement of sorghum for drought tolerance.

Association among traits

The analysis of correlation coefficient among traits showed that only dry root weight had positive and significant association with dry shoot weight (0.568**). This result suggested that any positive increase in dry root weight will accelerate the boost in dry shoot weight. However, non-significant association was obtained among leaf rolling, plant height; flag leaf length, flag leaf width, root length, dry shoot weight, dry root length, fresh root weight, leaf drying and No. of tillers (Table 4).

SUMMARY AND CONCLUSION

Selection for drought resistance is regarded as an economic and efficient way of eradicating agricultural problems particularly in dry areas. To achieve this goal, a set of reliable traits that can be rapidly screened is needed. For successful selection, presence of useful variability within the available germplams should exist. Therefore, in this study accessions TS217 and DA119 collected from Tigray and Amhara region respectively are found to have superior response characteristics as compared to the check (B35) when subjected to drought at pre-flowering stage followed by TS211 from Tigray. Therefore, the authors recommend use of these accessions especially TS217 as parent material in attempts to improve sorghum for drought tolerance. However, since this result is one year and one season data, not associated with any type of effects on yield so further analysis is needed and comparisons should include locally adapted accessions as well.

Conflict of Interest

The authors have not declared any conflict of interest.

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Assessment of heavy metals accumulation in paddy rice (*Oryza sativa*)

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Heavy metals contamination in paddy field was conducted using *Oryza sativa*. Paddy soils and rice plants were sampled along seven transverse lines of the paddy field before the harvesting time. The paddy plants were separated into roots, stems, leaves and grains. Metal concentrations of the samples were carried out using ICP-OES Spectrometer machine OPTIMA 5300 DV. Metals enrichment factor and translocation were also measured in this study. The results showed that the plant roots of *O. sativa* accumulated relatively large amount of lead, cadmium, chromium and copper, while zinc highest in the stem. The correlation test showed that there was a strong correlation for zinc and cadmium concentrations in *O. sativa* with the paddy soil. Enrichment factor (EF) showed that lead, cadmium and copper were concentrated in the root of *O. sativa*, while chromium and zinc metals were more concentrated in the shoot part. Translocation factor (TF) showed that *Oryza sativa* was able to transfer zinc and chromium from root to the shoot part of *O. sativa*. *O. sativa* has the potential of being used for the phytoremediation of zinc and chromium from the paddy soil.

Key words: Heavy metals, *Oryza sativa*, enrichment factor (EF), translocation factor (TF).

INTRODUCTION

The accumulation of heavy metals in agricultural soils is a growing concern to the public as well as government agencies, due to the food safety issues and potential health risks as it has detrimental effects on soils ecosystems (McLaughin and Singh, 1999; Yanez et al., 2002). Heavy metals such as arsenic, cadmium, and mercury, are of primary concern in soil and food contamination, particularly in rice cropping system, because of their toxicity (Reeves and Chaney, 2001). These toxic elements accumulate in the soils, induce a potential contamination on food chain, and endanger the ecosystem safety and human health (Reynders et al., 2008).

Sources of heavy metals in soils are mainly from natural occurrence, derived from the parent materials and from human activities (anthropogenic sources). Anthropogenic inputs are associated with industrialization and agricultural activities such as atmospheric deposition, vehicle exhaust, waste incineration, waste disposal, urban effluent, fertilizer application and the traditional application of sewage sludge as the fertilizer in agricultural land (Bilos et al., 2001; Hlavay et al., 2001; Koch and Rotard, 2001).

Crops have different abilities to absorb and accumulate metals in their different part, and a wide variation in metal uptake and translocation between plant species and even

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Figure 1. Map of Kompipinan, Papar distict, Sabah showing the sampling stations for paddy plants and soil.

between cultivars of the same species (Kurz et al., 1999; Arao and Ac, 2003; Liu et al., 2005; Yu et al., 2006). Plants absorb heavy metals from the subsurface of 25 cm depth zone of the soil where roots of most cereal crops are located (Ross, 1994; Mico et al., 2007). Once the adsorption of the heavy metals in the soil is saturated, more heavy metals would be distributed in the aqueous phase and the bioavailability of the heavy metals would subsequently be enhanced (Sridhara et al., 2008). Heavy metals in soil with high concentration will increase the potential of being taken up by plants. The pollutants will then be translocated from roots to shoots then to the grains, which is consumed by human population. Toxic metals are mostly geochemically mobile where they are readily taken up by plant roots and translocated to aerial parts (Satarug et al., 2003).

In Asia, rice is the most common crop grown on agricultural land. The total area of paddy fields has been estimated as over 1 million hectares and up to 50% of these are well cultured with high production of rice. According to Kitagishi and Yamane (1981), the dietary cereal intake, mainly rice by Asian is 574 g/day, which is about half of the total dietary intake. Thus, heavy metals existence in rice may have a large influence on metal intake by the human population. Therefore, this study was conducted to determine the extent of heavy metals (Pb, Cd, Cr, Cu and Zn) uptake by paddy plant (*Oryza sativa*) influenced by agricultural soils.

MATERIALS AND METHODS

Study area

The paddy fields were located at Kompipinan, Papar district, Sabah near quarries and main highway that link Papar district to Kota Kinabalu, within the area of latitude 05° 42′ 08.7″ N to 05° 42′ 12.6″ N and from longitude 115° 57′ 15.6″ E to 115° 57′ 13.8″ E. The sampling stations are shown in Figure 1. Seven sampling points within that area were chosen for this study. The exact position and coordinate for each sampling stations are shown in Table 1. Soil samples from the root zone were also taken.

Sample collection

Random sampling was carried out at the study site and the sampling frequency is twice (2) at each sampling points. The sample collections were conducted before harvesting time in the paddy field. Each paddy plant was uprooted together with its root, stems, leaves and seed. The soil samples were collected from the surrounding roots of the paddy plant using Ponar Grab sampler at a depth of 0 to 25 cm from the soil surface (Machiwa, 2010). The paddy plants and soil samples were inserted into labeled plastic bags and placed on ice while transported to the laboratory, then kept in the refrigerator at 4°C for preservation before analysis.

Table 1. Location of sampling stations for paddy plants and soil sample.

Station No.	Location
1	N 05° 42' 08.7" E 115° 57' 15.6"
2	N 05° 42' 10.6" E 115° 57' 15.0"
3	N 05° 42' 12.6" E 115° 57' 13.8"
4	N 05° 42' 12.4" E 115° 57' 13.1"
5	N 05° 42' 10.6" E 115° 57' 13.8"
6	N 05° 42' 10.3" E 115° 57' 14.5"
7	N 05° 42' 08.2" E 115° 57' 15.1"

Sample preparation

The paddy plants were washed using deionized water to remove residues of impurities, then separated into the roots, stems, leaves and grains. Each part was cut to smaller sizes for easier digestion. The grains were finely ground using mortar and pestle to separate the white rice from its husk, and then dried in an oven at 65°C for 24 h. Soil samples were manually cleaned to remove remnants of roots, stones, twigs and other impurities. The soil samples were then homogenized and dried at room temperature. The dried soil samples were pulverized using mortar and pestle, and sieved to obtain <63 µm size.

Digestion

1 g dried samples of roots, stems, leaves, seeds from *O. sativa* and soil samples were placed into 50-ml conical flask. Each parts of the *O. sativa* were digested in 10 ml of 65% nitric acid solution and heated on a hot plate with temperature of 120°C for 2 h until it produce clear solution. 1 g of soil samples were digested with 10 ml of aqua-regia HNO_3: HCL solution with 3:1 ratio and then heated on a hot plate with 70°C temperature for 4 h. After cooling, the *O. sativa* and soil samples were then diluted by 50 ml of deionized water and filtered with 45 µm size Whatman filter paper. Samples that have been filtered were placed into the polyethylene bottles and kept in 4°C refrigerator until heavy metal analysis were done.

Quantification of heavy metals

Heavy metal concentrations were determined using ICP-OES Spectrometer machine OPTIMA 5300 DV for lead, cadmium, chromium, copper and zinc elements. A quality control program was applied which includes duplicate samples, in house reference materials, reagent blanks and certified international reference materials (Ramsey et al., 1987; APHA, 1995; Eaton, 2005). The precision and bias of the chemical analysis was less than 10%.

Enrichment factor (EF) and translocation factor (TF)

Quantification of the enrichment factor and translocation factor are shown in the Equation (1) from Lorestani et al. *(*2011) and Equation (2) from Singh et al. *(*2010). The value of enrichment factors indicated the mechanism of heavy metals absorption from soil to *O. sativa;* however the translocation factor is to examine the transport or transfer of the heavy metals from roots to shoots of *O. sativa*. The EF and TF values for heavy metals that were examined in this study are in mg/kg.

$$Enrichment\ Factor\ (EF) = \frac{Cp}{Cs} \quad (1)$$

Where
Cp=heavy metal concentration in plant
Cs=heavy metal concentration in soil

$$Translocation\ Factor\ (TF) = \frac{Cs}{Cr} \quad (2)$$

Where
Cs=heavy metal concentration in plants' shoot
Cr=heavy metal concentration in plants' root.

RESULTS

Concentrations of heavy metals in *Oryza sativa*

The mean concentrations of heavy metals in *O. sativa* in this study showed that all metals were present in all parts of the *O. sativa* at different levels. Most of the metals concentrated in paddy roots, except for zinc which has the highest concentration in paddy stems as shown in Table 2. Concentrations of Cadmium, Copper and Zinc, except Lead, in paddy rice grains were within FAO/WHO (2002) permissible limits for human consumption.

Distribution of Chromium in *O. sativa* varied, and was in the order of root > leaf > grain > stem (Figure 2). Bhattacharyya et al. (2005) reported a similar result. Chromium concentration was higher in root than the shoot part due to redox reaction that occurs in the plants which causes the movement of Chromium from root to the shoot part. In addition, Chromium(III) can also react with carboxylic functional groups (-COOH) in plants which prevents the translocation of the metals from root to the shoot, thus the Chromium concentration in the shoot part is low (Bhattacharyya et al., 2005).

Copper concentrations varied in descending order from root > grain > leaf > stem (Figure 3). Results obtained in this study were similar to the study conducted by Yap et al. (2009) and Fu et al. (2008). Copper is one of the nutrients needed to process a variety of enzyme activity in plants (Hang et al., 2009). However, the presence of copper metal that exceeded the permissible limits or standards may cause stunted growth of roots and plants (Jiang et al., 2007).

For distribution of Zinc concentration, accumulation occurred in descending order of stem > root > grain > leaf (Figure 4). Zinc accumulated in the plant was due to the absorption of the metal by roots from the plants surrounding soil (Jiang et al., 2007). However Zinc is an important nutrient required by plants to synthesize proteins, for hormones growth and reproductive processes of plants. Adequate Zinc concentration in the leaves of plant is 15 to 50 mg/kg. Nevertheless, at levels above 200 mg/kg of Zinc will cause toxicity to the plants which can cause the stunted root growth and leaf undersized (Jiang et al., 2007).

Table 2. Mean concentrations (±SD) of metals (mg/kg) in paddy plants and paddy soils.

Parts \ Metals	Lead (Pb)	Cadmium (Cd)	Cromium (Cr)	Copper (Cu)	Zinc (Zn)
Root	7.70 ± 1.27	0.38 ± 0.09	5.46 ± 2.26	4.94 ± 1.03	16.08 ± 1.67
Stem	0.04 ± 0.02	0.11 ± 0.06	3.26 ± 1.87	0.38 ± 0.06	29.60 ± 7.04
Leaf	0.26 ± 0.14	0.11 ± 0.05	4.34 ± 2.01	0.71 ± 0.18	12.40 ± 2.72
Grain	2.06 ± 2.42	0.13 ± 0.08	4.12 ± 3.17	0.74 ± 0.32	12.75 ± 4.42
FAO/WHO Standards	**0.2**	**0.2**	**-**	**20**	**50**
Paddy soils	8.03 ± 1.07	0.32 ± 0.40	4.16 ± 0.68	6.62 ± 0.72	13.89 ± 1.63

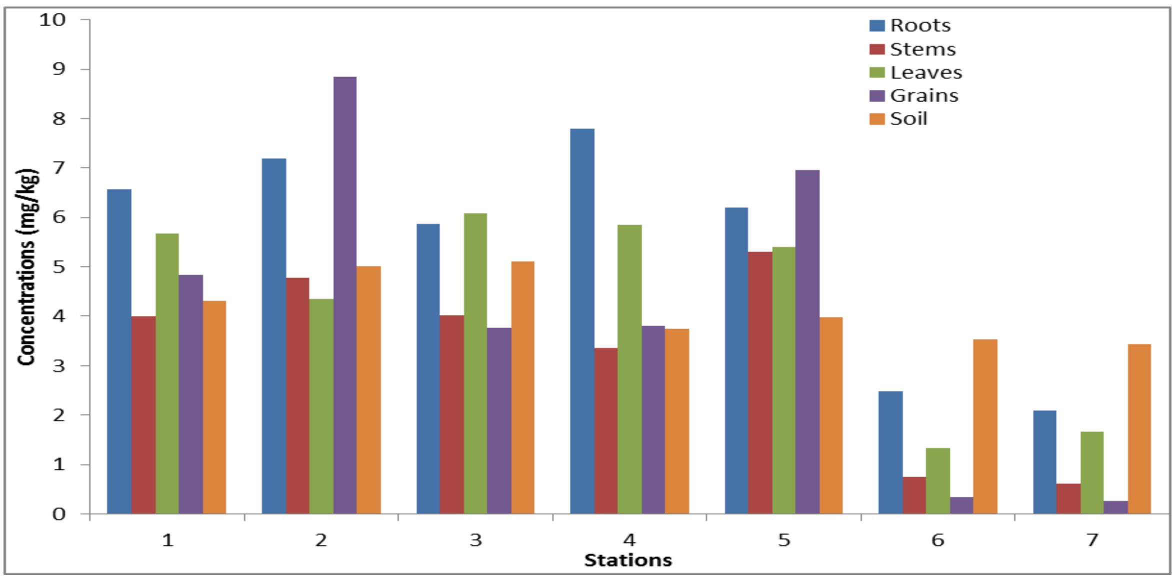

Figure 2. Distribution of chromium (Cr) in *Oryza sativa* and paddy soil.

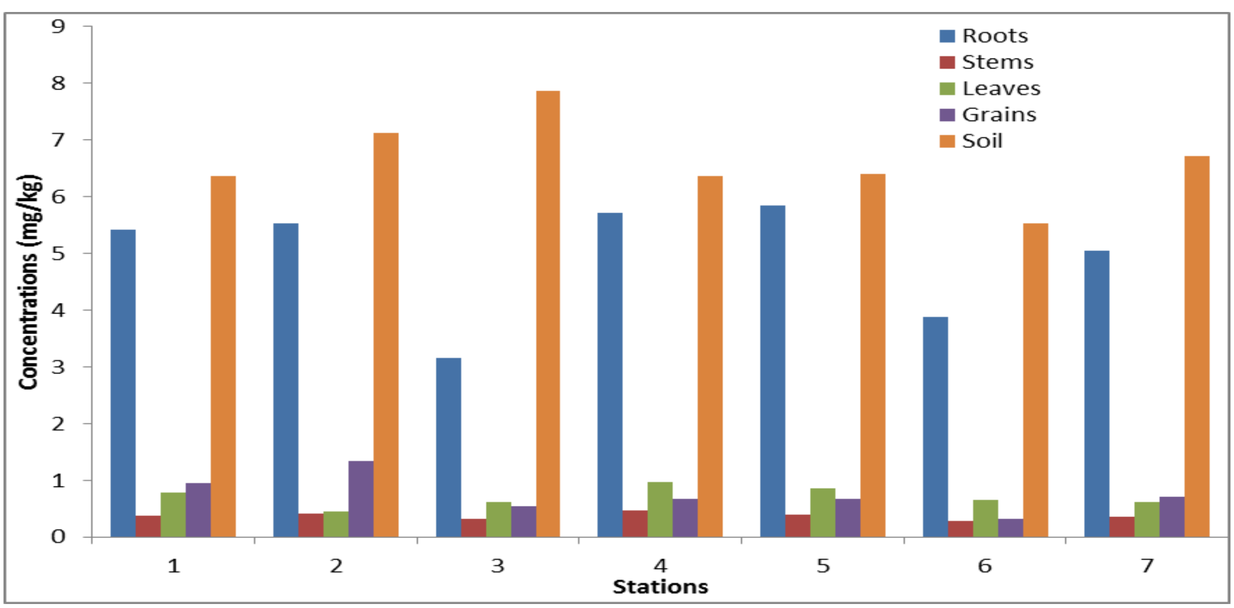

Figure 3. Distribution of copper (Cu) in *Oryza sativa* and paddy soil.

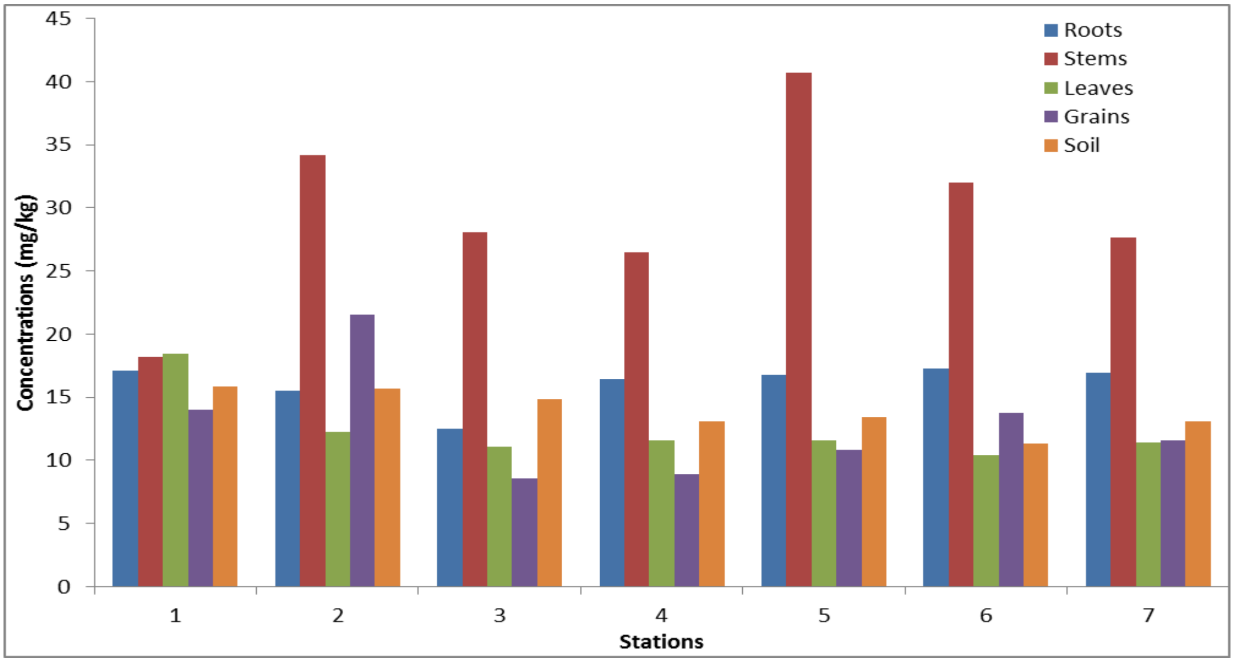

Figure 4. Distribution of zinc (Zn) in *Oryza sativa* and paddy soil.

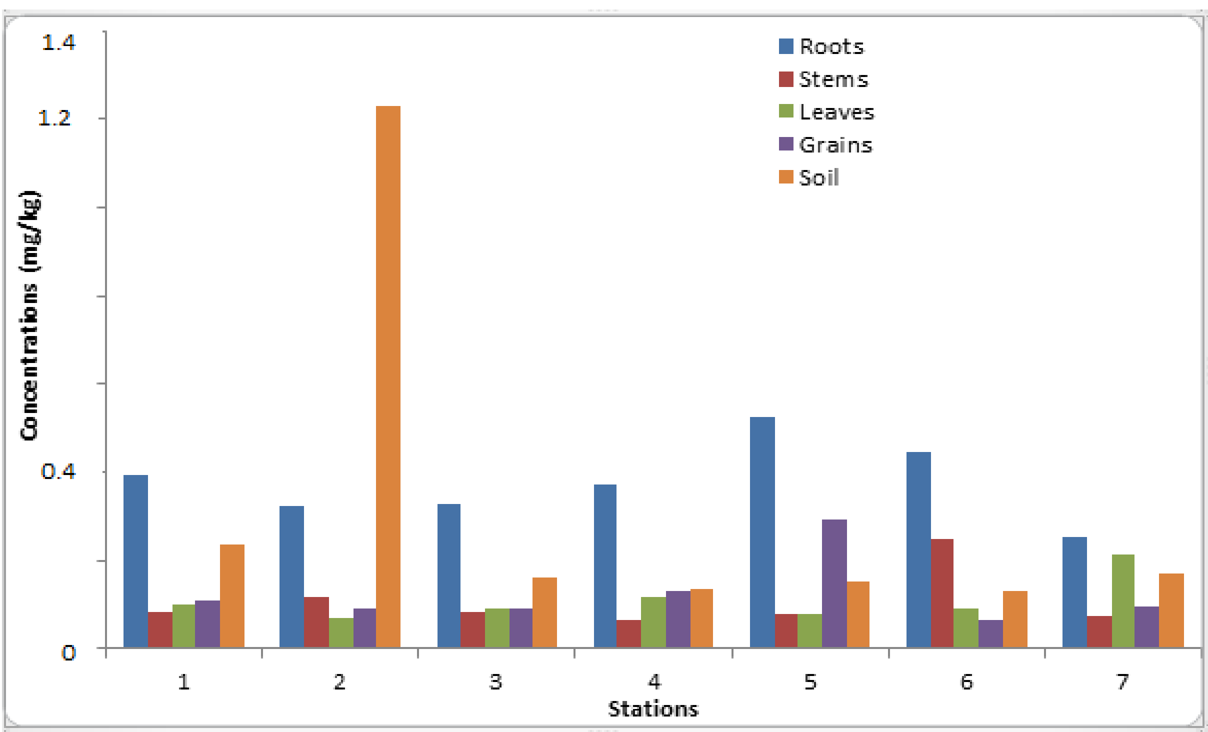

Figure 5. Distribution of cadmium (Cd) in *Oryza sativa* and paddy soil.

Cadmium concentration showed a decreasing pattern from root > grain > leaf > stem (Figure 5). Cadmium is one of the major pollutants produced in the industrial area (Horng et al., 2013). It is easily absorbed and spread to the whole paddy plant and its bioavailability in the soil. Cadmium metal uniformly dispersed in small

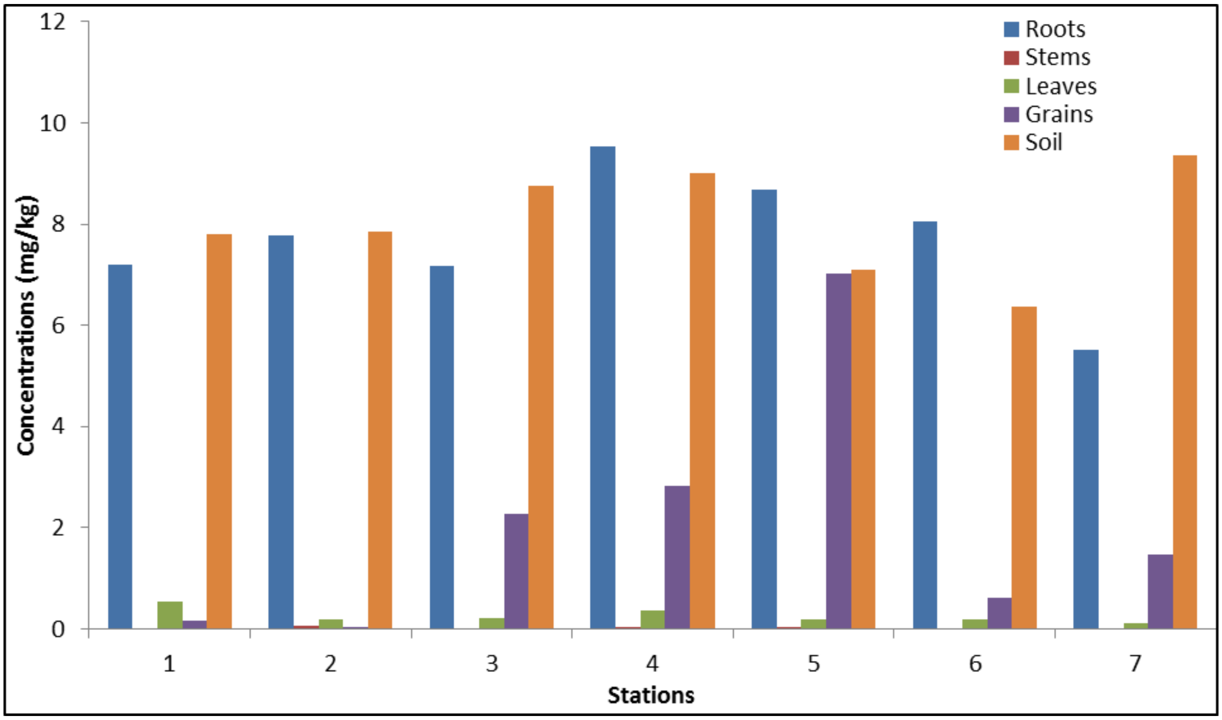

Figure 6. Distribution of lead (Pb) in *Oryza sativa* and paddy soil.

concentrations due to the nature of Cadmium that is readily absorbed by the plant and dispersed to the other plant parts in spite of its properties that does not carry vital nutrients to animals and humans (Yap et al., 2009). Lead concentrations varied in descending order of root > grain > leaf > stem (Figure 6). According to Li et al. (2007), most of the Lead that was absorbed in paddy plant is accumulated highly in roots compared to other parts of the plants. The possibility of Lead presence in *O. sativa* is believed to be due from the remnants of quarries and mining activities near the agricultural fields (Bliznakovska et al., 2013). Content of heavy metals in the soil also affects the intake of Lead in plants (Kachenko and Singh, 2004). Runoff from the road might also be a major source of Lead, which diffused into the soil and subsequently absorbed by plants that grow at the edge of the road (Xuedong et al., 2012).

DISCUSSION

Concentration of heavy metals in paddy soils

In this study, Chromium concentrations ranged in soil from 3.44 to 5.11 mg/kg. The use of phosphate fertilizers in agricultural activities will increase the Chromium metal content in crops as the fertilizer is manufactured from phosphate ore with high content of heavy metals such as Chromium, Lead and Iron (Saadia and Nabila, 2013). Copper concentration in *O. sativa* ranged from 5.54 to 7.86 mg/kg. Low level of copper in shoots part of paddy plants might be attributed to low dispersion and bioavailability of this metal in the soil (Fernandes and Fernando, 1990). Zinc concentrations in the soil ranged from 11.36 to 15.82 mg/kg. Zinc is produced in many environments through natural process and released from the earth's crust (Kennedy and Burlingame, 2003). Cadmium concentrations in the soil ranged from 0.13 to 1.23 mg/kg, while the range for Lead concentrations was between 6.37 to 9.35 mg/kg. Based on the results obtained, metal levels in the soils did not exceed the FAO/WHO (2002) permissible limits, except for Cadmium and Lead.

Enrichment factor (EF) and translocation factor (TF)

The absorption mechanism of heavy metals by *O. sativa* can be analyzed using enrichment and translocation factor analysis. Figure 7 shows the enrichment factor of metals from the soil to other parts of *O. sativa* which was in decreasing order of Zn (5.16) > Cd (4.12) > Cr (4.00) > Pb (1.28) > Cu (1.03). Based on the results obtained, the enrichment value for all studied metals were greater than 1, which indicates that the *O. sativa* is a hyper accumulator plant with high potential to absorb metals from the soil (Lorestani et al., 2011).

Translocation factor for selected metals from the roots to the shoots of *O. sativa* is indicated in Figure 8, and the trend showed that metal levels varied in descending order of Zinc (3.43) > Chromium (1.97) > Cadmium (0.94) >

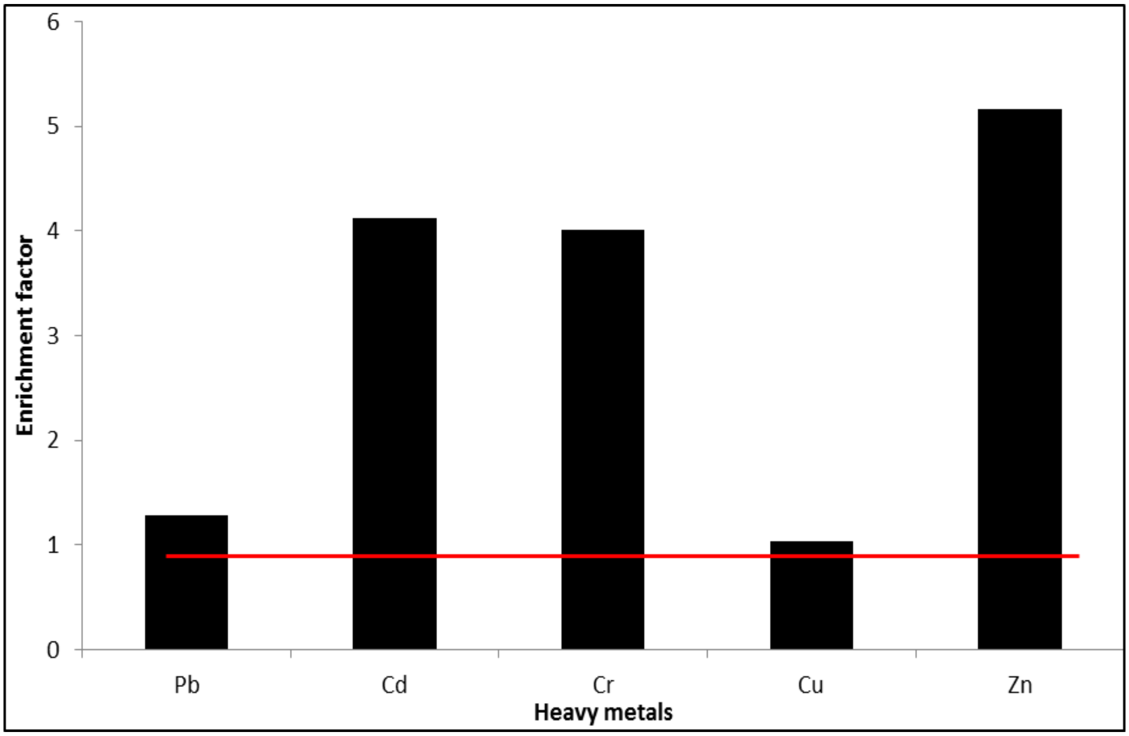

Figure 7. Enrichment factors of heavy metals from paddy soil to *Oryza sativa.*

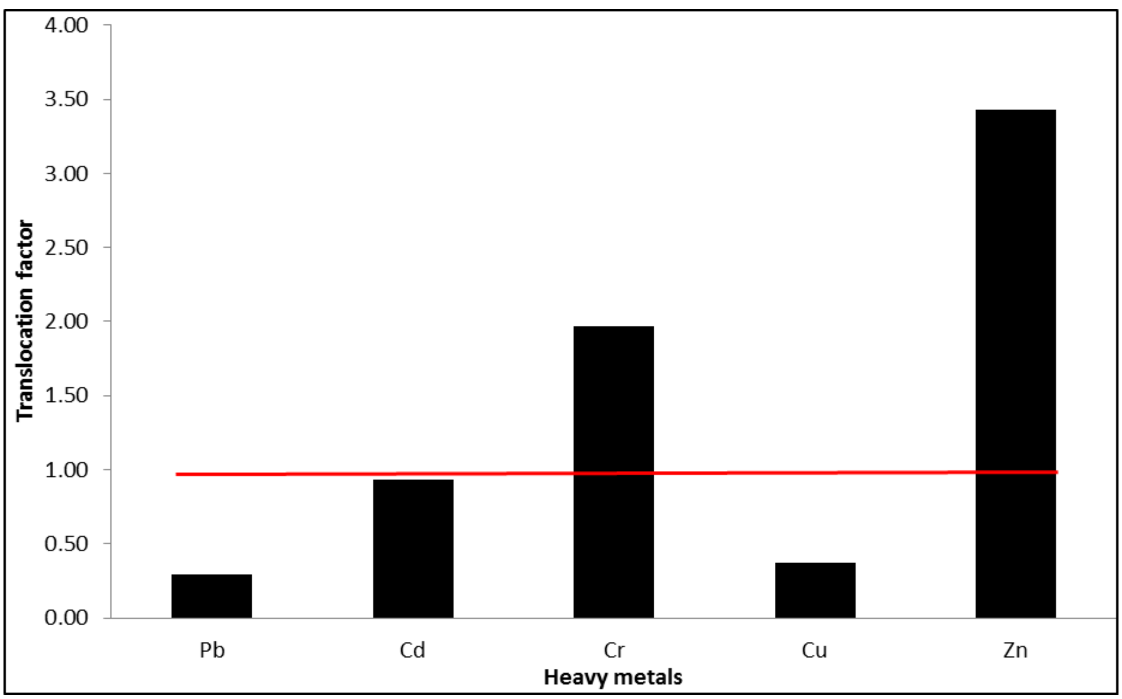

Figure 8. Translocation factor of heavy metals from the roots to shoots of *Oryza sativa.*

Copper (0.37) > Lead (0.29). The results showed that only Zinc and Chromium have the translocation factor value greater than 1, which means that *O. sativa* was able to hyper accumulate only Zinc and Chromium from roots to the shoots (Resvani and Zaefarian, 2011).

Statistical analysis

Correlation analysis (P < 0.05) was carried out to study the correlation of metals from *O. sativa* parts with the paddy soil. The results obtained show that there were strong correlations for Chromium in roots with stems (r = 0.87), leaves (r = 0.90) and grains (r = 0.80). Similarly, there was strong correlation for Chromium in the stems with leaves (r = 0.85) and grains (r = 0.93). However, for Copper, there was no significant correlation between all parts, except between roots and stems (r=0.81). There was a negative correlation between leaves and stems for Zinc metal with (r=0.07). Cadmium showed a moderate correlation for roots and grains (r=0.67). Correlation analysis showed that Chromium, Lead and Copper in *O. sativa* did not correlate significantly with the paddy soil. Studies conducted by Horng et al. (2013) indicated that Chromium showed no significant correlation between roots and other parts of *O. sativa*. However, the Chromium concentration showed a significant correlation between the stems, leaves and grains with each other. Miclean et al. (2013) reported a significant correlation for Lead, Cadmium and Copper in plants and its surrounding soil.

According to Horng et al. (2013), the significant relationship between parts of *O. sativa* and paddy soil was due to the presence of some residual soil particles in the plants during the analysis, and most of the heavy metals absorbed by plants were derived from the soil.

Conclusion

Heavy metals in this study accumulated abundantly in the root compared to other parts of *O. sativa*, except for Zinc which showed the highest concentration in the stem. The analysis of enrichment factor showed that Lead, Cadmium and Copper were accumulated more in the root part while Chromium and Zinc were accumulated more in the shoot part. Each heavy metal was present in a different concentration in every parts of the plant. The metal content in the *O. sativa* and paddy soil in this study does not exceed the permissible standard set by the FAO/WHO except for Cadmium and Lead. The translocation factor analysis showed that *O. sativa* was able to transfer only Zinc and Chromium metals from the root to the shoot, which implies that *O. sativa* has the potential to be used for the phytoremediation of Zinc and Chromium in paddy soil.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Characterization of village chicken production and marketing systems in selected districts of North Western Amhara region, Ethiopia

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A formal survey was conducted in three purposively selected districts of western Amhara, Ethiopia. The major objective of the study was to assess and characterize the existing chicken production and marketing system of the study areas. A total of 160 randomly selected chicken owners were used for the study. The result revealed that there were four chicken production systems in the study areas; scavenging only (2.5%), scavenging with seasonal supplementation (75%), scavenging with regular supplementation (21.9%) and intensive system (0.6%). Accordingly, the dominant (75%) chicken production system was a traditional type, using mainly (95.8%) local ecotypes, managed on scavenging with seasonal feed supplementation. The total chicken flock size/household (HH) was 13.7 with a hen to cock ratio of 4.6:1. The purpose of birds, in order of importance were sale for cash income (51.4%), egg hatching (45%), home consumption (44.3%), use of birds for religious ceremonies (36.4%) and egg production (40.7%). The result indicated that only 7.5% of village chicken owners prepared separate chicken houses for their birds and the rest (92.5%) kept birds in various night sheltering places. The average age of local cockerels at first mating and pullets at first egg were 24.6 and 27.5 weeks, respectively. The study revealed that 97.5% of chicken owners experienced disease problems in their area, mainly Newcastle disease (NCD) (98.2%). The average number of eggs laid/clutch was 13.3 eggs (ranged 10 to 16) and the number of total clutch periods/hen/year was 4 (ranged 3 to 6). The annual egg productivity of local hens, under the existing farmers' management condition was 51.6 eggs/hen (ranged 30 to 96). The average hatchability performance of local broody hens was 85.9%. However, survivability of locally hatched chicks was low (55.4%). Seasonal diseases outbreaks was the major (76.9%) cause for chicken death. Seasonality of prices was the major (75%) chicken and egg marketing constraint in the areas.

Key words: Local chicken ecotypes, scavenging, village chicken production systems.

INTRODUCTION

In most developing countries, village poultry makes up the largest proportion of the national poultry population (Gueye, 2000; Sonaiya and Olori 1998). In Ethiopia, chickens are the most widespread and almost every rural Family owns birds, which provide a valuable source of food and income (Tadelle et al., 2003). The total chicken population in the country is estimated to be 52.3 million with native chicken representing 48.8 million (96.9%), 0.27 million (0.54%) hybrid chicken and 1.29 million (2.56%) exotic chicken (CSA, 2012/13). However, the economic contribution of the sector is not still proportional to the huge chicken numbers, attributed to the presence of many productions, reproduction and infrastructural constraints (Aberra, 2000; Halima, 2007). Similar to the national system, the major proportion of chicken production (98%) in Amhara region (ANRS) is believed to be a traditional sector from which almost the whole annual meat and egg production is produced (ANRS-BoARD, 2006). According to CSA (2012/13); the total chicken population of the region is estimated to be 14.6 million, accounting to 27.9% of the national chicken population.

According to Cumming (1992), only little research and development works have been carried out on village chickens, despite the fact that they are more numerous than commercial chickens in most developing countries. In recent years, attention has been given to the characterization of local chicken ecotypes (Halima, 2007). A study carried out in northwestern Ethiopia showed that the growth performances of local ecotypes were comparable with exotic chicken breeds under intensive management conditions (Halima, 2007). As a result some promising local chicken ecotypes including Melo-Hamusit, Mecha, Tilili and Farta were recommended for further development and research interventions.

It is difficult to design and implement chicken-based development programs that benefit rural people without detail understanding village chicken production and marketing systems (Gueye, 1998). To date, there were no any detailed studies conducted in the home area of the above selected local ecotypes, targeted on a comprehensive description of the prevailing village chicken production and marketing systems, identification of production constraints and assessment of appropriate technological interventions that could be used to improve the breeds.

Therefore, this study was conducted to: 1) study and characterize the prevailing village chicken production and marketing systems of the study districts; 2) evaluate the performance of selected local chicken ecotypes under existing farmers' management condition; 3) assess the prevailing production and marketing constraints and suggest possible research and development interventions.

MATERIALS AND METHODS

Description of the study districts

The study was conducted on three districts (Guagsa-Shikudad, Mecha and Farta), northwestern Amhara region.

Guagusa Shikudad district

This district is a home for "Tillili chicken eco-type" which was selected as meat type. According to the district office of agriculture annual report (Guagusa Shikudad, 2002), the total human population and HH size of the district was 106,189 and 19,209, respectively. The total land size of the district was estimated to be 28576.4 ha. The average annual rainfall, altitude and temperature were 2356 mm, 2470 masl and 19°C, respectively. The district has a total of 30907chicken population size.

Mecha district

This district is a home for "Mecha chicken eco-type" which was selected as dual purpose breed. According to the district office of agriculture annual report (Mecha, 2002), the total human population and household (HH) size of the district was 272,499 and 72,404, respectively. The total land size of the district is estimated to be 156,027.0 ha. The average annual rainfall, altitude and temperature of the district were 1500 mm, 1800 masl and 24 to 26°C, respectively. The district has a total of 204181 chicken populations.

Farta district

This district is a home for *"Farta eco-type"* and "Melo Hamusit eco-type" which were selected as egg type. According to the district office of agriculture annual report (Farta, 2002), the total human population and HH size of the district was 243,629 and 49,033, respectively. The total land size of the district is estimated to be 107076.5 ha. The average annual rainfall, altitude and temperature of the district were estimated to be 1250 to 1599 mm, 1920 to 4235 masl and 9 to 25°C, respectively. The district has a total of 179,579 chicken populations.

Sampling techniques and data collection

A multi-stage sampling procedure was applied for the study. Two farmer kebeles from Mecha, two farmer kebeles from Guagusa-Shikudad and four farmer kebeles from Farta were selected purposely. Therefore, a total of 8 representative administrative kebeles were selected purposively. Then a simple random sampling technique was applied to choose 20 village chicken owners in each of the selected kebeles. Hence, a total of 160 village chicken owners were interviewed using a pre-tested structured questionnaire (Remark: Kebele is the lowest administrative structure below district).

Data management and statistical analysis

The qualitative and quantitative data sets were analyzed using SPSS software, version 12 (SPSS, 2002). More specifically descriptive statistics and general linear model (GLM) were used.

RESULTS AND DISCUSSION

Household characteristics

The average family size/HH in the study districts was 5.7

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Table 1. Household characterstics of village chicken owners in the study districts (N = 160).

Household characterstics	Study kebeles				Grand mean
	Tillili (n = 40)	Mecha (n = 40)	Farta (n = 40)	Melo (n = 40)	
Sex of respondents (%)					
Male	80	77.5	90	83	82.5
Female	20	22.5	10	17	17.5
Education status of respondents					
Illiterate (%)	37.9	35	37.5	43.1	38.38
Read and write (%)	33.8	42.7	29.61	33.63	34.94
Grade 1 - 6 (%)	20	16	16.2	18.11	17.58
Grade 7 - 12 (%)	3.1	4.3	3.1	4.25	3.69
Diploma and above (%)	5.2	2	13.59	0.91	5.43
Total family size in the household (Mean ±SE)	5.92 ± 1.9	5.7 ± 2.1	5.88 ± 1.5	5.35 ± 2.1	5.71 ± 1.9
Land holding/HH (ha)(Mean ±SE)	$0.81^{a} \pm 0.9$	$1.12^{ac} \pm 0.08$	$0.57^{a} \pm 0.04$	$1.31^{bc} \pm 0.24$	0.97 ± 0.07

[a,b,c]Least square means with different superscripts within a raw are significantly different ($p < 0.05$).

(ranged 1 to 10). There was no significant difference among study districts in family size/HH. The average family size identified in the study districts was higher than the national average of 5.2 persons (CACC, 2003) and the reported 5.4 for northwestern Amhara region (Halima, 2007). The average land holding per household in the districts was 0.97 ha (ranged 1 to 2.5 ha). There was significant difference among the study districts with related to average land holding. The result was lower than the reported 1.28 ha/HH of northwestern Amhara by Halima (2007), but similar with the national average of 1.02 ha (EEA, 2002) (Table 1).

Chicken management

Production system and flock size

The most dominant (75%) chicken production system identified in all the districts was free range with seasonal supplementation, comprised of 95.8% local chicken ecotypes. The other chicken production systems identified in the districts were scavenging only (2.5%), scavenging with regular feed supplementation (21.9%) and intensive production system (0.63%). Similarly, Halima (2007) reported that the most dominant (99.2%) chicken production system in northwest Amhara region was scavenging type with only seasonal feed supplementation. The average flock size/HH was 13.7 birds (ranged 1 to 54). The result indicated that there was no significant difference among study areas with related to chicken flock size/HH (Table 2).

The result was in line with the figures of Gueye (1997), who reported 5 to 20 birds/HH in most African countries. However, a relatively higher chicken flock size/HH (19 birds), with a hen to cock ratio of 4.4:1, was reported by Khalafalla et al. (2001) in Sudan. Similarly, a flock size of 16 birds/HH was reported in the central highlands of Ethiopia by Tadelle et al. (2003). However, the result was higher than the report of Halima (2007) in northwestern Amhara, which was 7.4 birds/HH. The result of this study showed that the average chicken flock size per household is increasing in the region. The result of the study indicated that chicken flock size/HH varied between seasons of the year which is highly related to the availability of feed, prevalence of diseases and occurrence of predators.

The major (25.2%) type of exotic chicken breed produced by smallholder farmers of the study districts were Rhode Island Red (RIR) and their crosses with local chicken. The major (55%) sources of exotic chicken breeds were Regional Bureau of Agriculture and other farmers. Poor availability of improved chicken breeds (36.6%) was the main reason raised by interviewed farmer for not rearing exotic breed at large-scale. The majority of interviewed chicken owners (75.6%) prefered to keep more birds (large flock) only during the dry season, when availability of supplementary feed is better and risk of predators is low.

Chickens eco-types and their importance

The result indicated that local chicken eco-types found in the study districts showed phenotypic heterogeneity in terms of plumage color, shank length, growth and comb types. Red was the dominant (53.9%) plumage color followed by white (46.1%). In addition, red was the most preferred (83.6%) color, followed by white (83.5%). Regarding comb types, both single and double comb types were available in the study districts, while double comb was the most preferred (81.1%). The selection of color and comb type was mainly attributed to the market preference and presence of cultural attitudes.

Table 2. Average chicken flock size per household in the study districts (N = 160).

Parameter	Study districts: Guagusa Shikudad (n = 40) (Mean ±SE)	Mecha (n = 40) (Mean ±SE)	Farta (n = 80) (Mean ±SE)	Overall: Mean ±SE	Range
Young chicks	$1.08^{a} \pm 0.43$	$5.08^{b} \pm 0.68$	$1.96^{a} \pm 0.4$	2.5 ± 0.33	0 - 15
Pullets	$0.28^{a} \pm 0.12$	$1.53^{b} \pm 0.29$	$0.48^{a} \pm 0.1$	0.69 ± 0.1	0 - 6
Cockerels	$0.23^{a} \pm 0.13$	$0.85^{b} \pm 0.25$	$0.18^{a} \pm 0.05$	0.36 ± 0.1	0 - 7
Hens	2.93 ± 0.31	3.88 ± 1.31	2.17 ± 0.14	2.79 ± 0.4	0 - 54
Cocks	0.48 ± 0.09	1.08 ± 0.35	0.44 ± 0.07	0.61 ± 0.1	0 - 3
Total flock size	9.6 ± 1.23	14.1 ± 3.53	10.5 ± 0.82	13.7 ± 1.1	1 - 54

^{a,b} Least square means with different superscript within a raw are significantly different ($p < 0.05$)

The purpose of village birds, in order of importance, were sale for cash income (51.4%), egg hatching (45%), home consumption (44.3%), use of birds for religious ceremonies (36.4%) and egg production (40.7%). Similarly, Tadelle and Ogle (1996) reported that the major purposes of village birds in central highlands Ethiopia were sale for income (26.6%), use of sacrifice/healing ceremonies (25%), replacement (20.3%) and home consumption (19.5%).

Hatching for replacement was the first (71.7%) function of eggs in the study areas. The second and third purposes of eggs were sale for cash income (58%) and home consumption (68.6%), respectively. Similarly, Tadelle and Ogle (1996) reported that the major uses of eggs in central Ethiopian highlands were hatching for replacement (51.8%), sale for cash income (22.6%) and home consumption (20.2%).

Chicken husbandry practices

Feed and feeding

Although scavenging was the major feed source for village birds in all the study districts, 96.3% of interviewed chicken owners provided supplementary feeds, especially during feed shortage seasons. The majority (55%) of village chicken owners provided supplementary feed during the wet season only, while the rest (45%) provided throughout the year. July, August and September were the most critical feed shortage months of the year. Both homes produced grains and household leftovers were the major kinds of feeds stuffs (50.6%) supplemented by chicken owners. The major (72.1%) source of supplementary feed for village birds in the study areas was crop harvest.

Majority of the farmers (78.6%) did not have feeders. Lack of awareness and knowlege was the major reason for absence of feeders. The result of the study showed that all village chicken owners of the study areas provided water to birds; 83.75% only during the dry season and the rest 16.25% throughout the year. Concerning the frequency of watering, most chicken owners (78.9%) provided *ad libtum*. Spring water (33.1%), underground water (26.9%), hand operated pipe water (19.4%) and rain water (20.6%) were the main source of water for village birds.

Housing system

From the total of 160 village chicken owners interviewed, only 12 households (7.5%) constructed separate overnight houses. However, the majority (92.5%) of village chicken owners did not construct over night houses and keep birds on various night sheltering places including perches inside the house (59.9%), on the floor covered by bamboo made baskets (10.6%), on ceilings of the house (18.9%) and under locally constructed sitting place (3.1%). Lack of attention to village chicken production (44.6%), lack of construction materials (15%), lack of knowledge and awareness (20.6%), risk of predators (12.1%) and shortage of labor and time (4.4%) were some of the major reasons mentioned by chicken owners for not constructing a separate house for village birds.

Risk aversion strategies

The result of this study indicated that 69.3% of chicken owners reared birds mainly during the dry season, when the risk of disease outbreak and predation is low. Only 30.7% of village chicken owners reared birds throughout the year. It is identified that 95.4% of those chicken owners, who reared birds throughout the year, used various types of risk aversion strategies. Accordingly, reduction of flock size and keeping only some productive birds (84.6%) was the most preferred strategy implemented by chicken owners.

Production and reproduction performance of chicken

The average weight of hens and cocks is presented in

Table 3. Average weight of local hens and cocks in the study districts (N = 320 birds).

Parameter	Study districts			Over all	
	Guagusa Shikudad (N = 80) (Mean ±SE)	Mecha (N = 80) (Mean ±SE)	Farta (N = 160) (Mean ±SE)	Mean (N = 320) (Mean ±SE)	Range
Average weight of local hens (kg)	$1.3^c \pm 0.1$	$1.2^b \pm 0.04$	$1.02^a \pm 0.03$	1.12 ± 0.021	0.6 - 2.1
Average weight local cocks (kg)	$1.5^a \pm 0.041$	$1.6^b \pm 0.063$	$1.11^a \pm 0.036$	1.4 ± 0.31	0.6 - 2.5

[a,b] Least square means with different superscript within a raw are significantly different ($p < 0.05$).

Table 4. Performance local hens under farmers' management condition (N = 320).

Parameter	Study districts			Over all	
	Guagusa Shikudad (N = 80) (Mean ±SE)	Mecha (N = 80) (Mean ±SE)	Farta (N = 160) (Mean ±SE)	Mean (N = 320) (Mean ±SE)	Range
Eggs laid/clutch	13.4 ± 1.4	13 ± 0.2	13.2 ± 0.2	13.2 ± 0.1	10 - 16
Average number of eggs set	13 ± 0.2	12 ± 0.2	12.2 ± 0.2	12.2 ± 0.1	7 - 16
Number of eggs hatched	11 ± 0.3	10.2 ± 0.2	10.5 ± 0.2	10.5 ± 0.1	6 - 15
Number of chicken survived	5.7 ± 0.3	5.5 ± 0.2	5.9 ± 0.2	5.8 ± 0.1	2 - 10
Survivability percentage (%)	53.7 ± 2.4	54.7 ± 2.4	56.7 ± 1.8	55.4 ± 1.2	20 - 100
Hatchability percentage	85.7 ± 1.5	85.3 ± 1.4	86.3 ± 1.2	85.9 ± 0.8	50 - 100
No of clutch periods/year/hen	3.9 ± 0.1	4 ± 0.1	3.9 ± 0.1	3.9 ± 0.1	3 - 6
Egg production/hen/year	52 ± 1.6	51 ± 1.8	52 ± 1.5	51.6 ± 1	30 - 96

Table 3. Significantly, higher weight was recorded at Mecha district. It was highly related with the availability of grains in Mecha districts better than the other districts. The average age of local cockerels at first mating and pullets at first egg were 24.6 weeks (5.74 months) and 27.5 weeks (6.42 months), respectively. Similar studies by various authors also indicated that the age at sexual maturity for female birds were 28 weeks in Tanzania (Katule, 1992), 24 weeks in Mali (Kassambara, 1989), 32 weeks in Sudan (Wilson, 1979), 28 to 36 weeks in Benin (Assan, 1990) and 25 weeks in Senegal (Sall, 1990).

The productive and reproductive performance of local hens is presented in Table 4. Accordingly, the average number of eggs layed/clutch and annual productivity of local hens was 13.2 (ranged 10 to 16) and 51.6 eggs (ranged 30 to 96), respectively. The average number of eggs/clutch identified in this study was similar with the reported 9 to 19 eggs in northwest Ethiopia by Halima (2007), 12 to 18 eggs in Nigeria by Gueye (1998) and 6 to 20 eggs in Tanzania by Aichi and Kitalyi (1998).

Division of household labor in chicken production

The result of the study showed that all family members envolved in chicken husbandry and marketing practices. Men were responsible for few activities like construction of shelter (97.5%) and taking sick birds for treatment (89.3%). However; women were highly responsible for many activities like cleaning birds' house (38.6%), feeding birds (80.7%), selling birds (46.8%) and selling eggs (54.6%). Children also participated in various husbandry activities like cleaning of birds' house, provision of feed and water to chicken.

Challenges of village chicken production system

Seasonal disease out break

High incidence of diseases, mainly Newcastle disease (NCD) was the major (76.9%) constraint for the existing village chicken production system of the study districts. According to interviewed chicken owners, mortality of village birds due to disease outbreaks was usually higher during the starts of the rainy season, mainly on April (66.8%) and May (31.4%). Serkalem et al. (2005) also reported that NCD was one of the major infectious diseases affecting productivity and survival of village chickens in central high lands of Ethiopia. The availability of vaccines and veterinary drugs to village chicken producers was generally poor in all study areas. It is also discovered that the available vaccines and drugs were relatively expensive and sold in large quantity batches (for example, in 350 doses for NCD vaccines) that they were uneconomic for farmers, who generally keeps a small sized flock.

Control of chicken diseases in the study areas could be achieved through improvement in veterinary and advisory services. It is also found vitally important to conduct further detailed studies focusing on identification NCD virus strain and prevalence rate of Infectious bursal disease (IBD) in the study areas so that preventive and control programs could be formulated.

Predation (impact of predators)

Predation was the second major (80.6%) constraint for village chicken production system of the study areas. According to village chicken owners, wild birds were the major (59.3%) predators affecting village chicken in the study areas. According to interviewed chicken owners, keeping birds at home (47.9%) and killing predators (33.9%) were the most preferred control mechanisms of predators. The problem of predators dictated that preparation of ‘predator proof’ chicken houses could help to reduce losses, especially during the night.

Low productivity of local chicken eco-types

The result of the survey revealed that the productive performance of village chickens in the study areas was relatively low as compared to improved breeds. However, they were highly adapted to the adverse climatic and management conditions of the study areas. Most chicken owners showed a great interest towards rearing improved breeds, so as to upgrade the blood levels of their local birds and improve their productivity.

Poor chicken management

According to the response of interviewed chicken owners and visual observation, awareness of farmers with regarding modern chicken husbandry practices was very low. Village chicken producers should get successive trainings to improve their awareness and knowledge towards modern chicken husbandry practices.

Chicken and egg marketing systems

Characteristics of chicken and egg markets

It is identified that 96.9% of interviewed farmers involved in chicken and eggs marketing activities. The result revealed that there was no any formal chicken and egg marketing operation in the study districts. Village chicken producers, consumers and middle men were identified to be the major actors involved in the system. Marketing of chicken and eggs in the study districts takes place in various places including farm gates (6.9%), village markets (31.2%) and urban market (61.9%). Product type (sex, age, color, and comb type), season (dry and wet), market type (urban and rural markets), market day types (holyday market and ordinary market days) and fasting seasons were some of the major factors that determine the price, supply and demand of chicken products in the study districts.

Chicken and egg marketing constraints

The result of the current study indicated that religious/cultural/holydays were highly associated with marketing and consumption chicken products. Orthodox Christian fasting periods were highly related with decreased consumption/demand/of chicken meat and egg. Fluctuation (seasonality) in prices of chicken products was the major (95.3%) chicken and egg marketing constraint of the study areas. Other marketing constraints identified in the areas included the following: low supply (output) of marketable chicken products, presence of only limited market outlets, lack of appropriate chicken and egg marketing information, lack of demand during fasting periods, lack of chicken transportation and egg handling facilities, lack of credits and capital to expand chicken production marketing activities.

Agricultural extension service

The result of the study indicated that only 38.2% of interviewed farmers responded that they are getting agricultural extension service with related to modern chicken husbandry practices.

Conclusion

The result of the study indicated that local chicken ecotypes were dominant for the existing production system. Seasonal disease out break was the major village chicken production constraint of the study districts followed by predation. This showed there is a need to intervene to reduce chicken mortality and improve productivity.

RECOMMENDATION

1) This study revealed that the productivity of local chicken eco-types could be enhanced by relatively simple changes in management and breeding interventions such as mass selection of promising eco-types, proper housing, proper feeding, health care, etc.

2) Control of diseases, mainly NCD, was found very critical. It could be achieved through improvement in

veterinary and advisory services.
3) Provision of proper trainings to chicken producers on modern husbandry could be important to improve the awareness of producers.
4) Provision of appropriate marketing information to village chicken producers could be important for the improvement of chicken and egg marketing system of the study districts.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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Full Length Research Paper

Erosion tolerance index under different land use units for sustainable resource conservation in a Himalayan watershed using remote sensing and geographic information system (GIS)

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Water erosion induced land degradation is a serious problem in the Himalayan hills of India. This paper presents an approach to analyze and assess the land use-wise soil erosion risks using Revised Universal Soil Loss Equation (RUSLE), fuzzy function, and remote sensing and GIS. Erosion tolerance index (ETI) was computed by integrating potential annual soil loss and soil loss tolerance limits for each landscape unit for the Bino watershed (296.17 km^2), Ramganga catchment, Uttarakhand. The thematic maps were generated using digital elevation model (DEM), remote sensing and geographic information system (GIS). Soil loss tolerance limits (T) by a set of fuzzy functions and soil characteristics, and potential soil loss rates (A) by RUSLE model. Potential annual soil loss varied from 0.49-3.64, 1.93-8.83, 4.07-55.49 Mg ha^{-1} in the lower, middle and higher slopes, respectively. The calculated soil loss tolerance limit (SLTL) values in the study watershed ranged from 2.5-10 Mg ha^{-1} yr^{-1}. The SLTL values for lower, middle and high slopes varies from 3.1-10.0, 5.0-10.0 and 6.7-10.0 Mg ha^{-1}, respectively. A total of 135 ETI values have been generated for different landscapes and slope classes. In higher slopes ETI values for open forest, dense forest, rainfed agricultural land, irrigated agricultural land and waste land varied from 0.170-0.249, 0.439-1.0, 0.117-0.130, 0.216-0.389 and 0.121- 0.137, respectively. The lowest ETI has been found in the Bino sub-watershed, whereas the highest for Syalde sub-watershed in all slopes, however the highest (0.38) weighted ETI value has been observed for Syalde sub-watershed and the lowest (0.212) for Gaya Gadhera sub-watershed. The results revealed the highest priority for Gaya Gadhera and least priority for Syalde sub-watershed. The approach for quantifying ETI and prioritization map developed in the study may serve as a guide for policy makers to decide effective watershed management plan.

Key words: Watershed prioritization, planning, soil loss, erosion tolerance, landuse units.

INTRODUCTION

Land degradation like climate change is an anthropogenic induced process and poses biggest threat to the sustainable livelihood security of the farming communities across India. All these factors combined with increased rate of land degradation are contributing towards a decline in agricultural productivity leading to food insecurity. Again, per capita availability of inelastic land resource is rapidly declining in relation to the annual population growth of 1.4% in the country (ICAR, 2010). The average rate of soil loss in the steeply sloping Indian Himalayan region is more than 20 Mg ha^{-1} $year^{-1}$ with a higher limit of 80 Mg $ha^{-1}year^{-1}$ (Samra et al., 2002). The state of Uttarakhand has 92.57% area under hills of Himalayan ranges and 7.43% under valleys and plains. As a consequence of higher erosion in this region, top soil fertility and crop productivity are declining and rivers, canals and reservoirs are silting-up.

Therefore, maintaining and enhancing the productive potential of land resources is vital by progressive introduction of sustainable technologies on a watershed basis, and thereby resilience in crop production. The generation of soil erosion and sediment outflow are the combined effects soil system, rainfall conditions, topography, cropping system and conservation practices or management. However in the soil erosion process, erosion limits need to be defined in order to keep the on-site and off-site impacts at acceptable levels. Soil loss tolerance (T) is 'the maximum rate of annual soil erosion that will permit a level of crop productivity to be obtained economically and indefinitely' (McCormack et al., 1982). The 'T' value is also sometimes called 'permissible soil loss' due to the fact that the rates of soil erosion and soil formation are in equilibrium at this level and must be determined in a scientific manner (Li et al., 2009). However, before any meaningful soil conservation intervention methods could be implemented, there is a need to determine the erosion hazard associated with watersheds for prioritization. In India mostly prioritization of watersheds has been carried out based on the sediment yield index and geomorphologic characteristics using remote sensing and geographic information system (GIS) tools. Conceptually, sediment yield outflow from a watershed does not provide a true representative erosion status of different parts of the large watershed. The overall sediment outflow may be less due to the implementation of conservation measures even though in certain locations of the watershed there could be higher soil erosion (A). While considering watershed conservation work, it is not feasible to take the huge area at once as implementation of watershed management programs involves huge financial and human resources. Further, for the success and sustainability of land use, prioritization must be based on a proper evaluation of all the potential uses of each unit of a landscape (Huston, 2006) after gathering requisite information on physical and biological characteristics (*viz.* hydrology, soil, land use and topography) of a landscape.

Therefore, it seems logical to include both soil loss tolerance limit (T) and potential soil erosion in the prioritization process and it is better to prevent erosion in vulnerable areas than to rehabilitate already eroded areas and treating the land from the actual soil loss value to soil loss tolerance limit (SLTL) with a better watershed management plan. The increasing use and capability of geospatial tools integration with environmental parameters offer opportunities to utilize these tools for the effective management of information for planning purposes. Thus, the present study is an attempt aimed at comprehensive investigation of environmental aspects of the watershed management in real-time perspective using remote sensing and GIS techniques.

The main objectives of the study were to assess the potential soil loss, to determine the soil loss tolerance limit (SLTL) and to quantify erosion tolerance index from each land use and slope class for comparing SLTL with the expected soil loss and then prioritization of sub-watersheds for further planning of soil and water conservation measures implementation in the Bino watershed of Uttarakhand. The working hypothesis for this study was that soil loss from the watershed would be higher than the soil loss tolerance *T* at each land use and slope class which was found a single value for the study watershed as per Mandal (1999) and thus erosion tolerance index may decrease with increase in slope gradient.

MATERIALS AND METHODS

Study area and thematic maps

The study was conducted in the Bino watershed under river Ramganga, a major tributary of the river Ganga that originates in the outer Himalayas in Chamoli district of Uttarakhand and drains into river Bino. It is situated at 79°6′14.4″ to 79°17′16.8″ E longitude and 29°47′6″ to 30°02′9.6″ N latitude in Almora and Pauri Garhwal district of Uttarakhand. The climate of the watershed varies from Himalayan sub-tropical to sub-temperate with mean annual maximum and minimum air temperature of 30 and 18°C, respectively. The daily mean temperature remains higher during the months of May and June and minimum in December and January. The mean annual rainfall in the area is 931.3 mm.

Remote sensing and GIS were employed in collection, analysis and presentation of all related data for the study because of their synoptic, multi-spectral and multi-temporal nature for effective mapping, monitoring and understanding the geomorphology and landuse system. The boundary of Bino watershed was delineated using SOI Toposheets (53 N/4, 53 N/8, 53 O/1, and 53 O/5) with 1:50,000 scale and ArcGIS 9.3 software developed by ESRI and then divided into 9 sub-watersheds *viz.* Bino Nadi, Masangari Nadi, Basolagad, Gaya Gadhera, Baya Gadhera, Chauna, Juniya Gadhera, Tamadhaun and Syalde, as done by District Watershed Mission (DWM), Dehradun and Central Soil and Water Conservation Research and Training Institute, Dehradun. Sub-watershed boundaries were also digitized in GIS environment with Geographic Coordinate System and further projected to WGS 1984

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Table 1. Representative indicator for each fuzzy function with corresponding weight.

Function	Indicators	Weights
Accommodate water entry	Final infiltration rate saturated hydraulic conductivity	0.35
Water transport and retention	Bulk density	0.10
Resist physical degradation	Water stable aggregates K-factor	0.25
Resist bio-chemical degradation	Organic carbon (O.C.)	0.15
Sustain plant growth	Fertility status N, P, K	0.15 (0.05,0.05,0.05)
Total score		1.00

Source: Mandal et al. (2009).

with UTM zone 44 N and then the area and perimeter of each sub-watershed and watershed were calculated using 'calculate geometry' option in geographic information system (GIS).

The downloaded ASTER digital elevation model (DEM) of 30 × 30 m resolution was processed to get the extract DEM and then contour map at 10 m interval was prepared. Slope map of the watershed was created in GIS and then reclassified by dividing into 8 classes, that is, 0-1, 1-3, 3-5, 5-10, 10-15, 15-25, 25-35, 35-50 and >50% following the guidelines of All India Soil and Landuse Survey, New Delhi. The FCC of Indian Remote Sensing (IRS) satellite image LISS-III 1-C collected from Indian Institute of Remote Sensing (IIRS), Dehradun for the year 2006 on a scale of 1: 50,000 was used to prepare landuse map using ERDAS IMAGINE 9.0 software. The landuse map was prepared through unsupervised classification assigning 150 classes initially and then merged into six classes based on the image characteristics like tone, texture, shape, colour, association, background, etc. following standard visual interpretation techniques and ground truth and the information available from landuse reports and field surveys. Land uses were classified as dense forest, open forest, rain-fed agriculture, irrigated agriculture, waste land, and water bodies.

Study on soils

Soil mapping units (SMUs) were delineated by taking into account land slope and landuse together using 'decision tree classifier' in environment for visualizing images (ENVI) Version 4.4 software. The land slopes mentioned earlier were divided into three classes, such as lower (<9%), medium (≥9% - <33%) and higher (≥33%) slopes, and land uses were put into 7 classes (including unclassified area). In this way, by using different expressions at decision nodes, the study watershed was divided into totally 21 classes and executed in landuse classification map of 2006 to get the final soil mapping unit map for the entire study area.

After delineation of soil mapping unit, soil sampling points were decided and soil samples representing all land uses and slopes were collected. Soil samples were collected for 15 different combinations of 3 slopes and 5 land uses (except water body and unclassified areas). For these 15 combinations, a total of 45 sampling points were selected and a point map was generated using GIS. The geographic location of each sampling point was identified in the field using GARMIN Global Positioning System (GPS) and from each location soil samples were collected from two depths (0-15 and 15-30 cm). Bouyoucos Hydrometer method was used to determine the percentage of sand, silt and clay. Bulk density and saturated hydraulic conductivity of soil was derived by Soil Texture Triangle Hydraulic properties calculator, EC by EC Meter, pH (1:2.5) in water by Beckman Glass electrode pH meter and organic C content by modified Walkley and Black method, available N by Alkaline $KMnO_4$ method using Nitrogen Analyzer (Gerhardt), available P by Colorimetrically by Olsen's extraction method and available K by 1 N Neutral NH_4OAC extraction using Flame Photometer.

Data analysis

An erosion tolerance index (ETI) was established from the integration of soil loss tolerance (T-value) and average annual soil loss (A). Model functions used for fuzzy membership classification of land attributes are based on the Semantic Import model (SI) approach. With this approach, the most relevant indicators representing various functions were selected first (Table 1), allowing maximum erosion as long as it was able to perform these functions and then transforming measured values of indicators into a common membership grade (0-1) through fuzzy modeling (Wymore, 1993; Mandal et al., 2009) according to the class limits specified by McBratney and Odeh (1997). If *MF (xi)* represents individual membership function (MF) values for i^{th} land property *x*, then, the basic SI model function took the following form in the computation process:

$$MF(x_i) = \left[1 \big/ \left(1 + \{(x_i - b)/d\}^2\right)\right] \quad (1)$$

where, b is central concept and d is the width of transition zone. As there were 'n' soil characteristics to be rated, the membership function values of individual soil characteristics under consideration were then combined using a convex combination function to produce a joint membership function (JMF) of all attributes, Y as follows.

$$JMF(Y) = \sum_{i=1} \lambda_i MF(x_i) \quad (2)$$

where *Y* is the convex membership functions (JMF) of all attributes, λ_i is the weighting factor for the i^{th} soil property *x*, and $MF(x_i)$ is the membership grade for the i^{th} soil property *x*.

Model functions used for fuzzy membership classification of soil attributes are based on the Semantic Import (SI) approach which utilizes a bell shaped curve (Burrough et al., 1992). This approach consists of two basic functions: symmetric and asymmetric.

i. Asymmetric left (Model 3): 'more is better'

$$MF(x_i) = \left[1 \big/ \left(1 + \{(x_i - b_1 - d_1)/d_1\}^2\right)\right] \quad \text{if } x_i < (b_1 + d_1) \quad (3)$$

ii. Asymmetric right (Model 4): 'less is better'

Table 2. Categorical ranking of soil attributes used in the study.

Soil attribute	Ordinal/categorical ranking					
	1	2	3	4	5	Model used
Saturated hydraulic conductivity (cm h^{-1})	<1.0 (0.2)	1.0-2.0 (0.3)	2.0-3.5 (0.5)	3.5-5.0 (0.8)	>5.0 (1.0)	3
Bulk density (Mg m^{-3})	<1.40(1.0)	1.4-1.47 (0.8)	1.48-1.55 (0.5)	1.56-1.62 (0.3)	>1.63 (0.2)	4
K-factor (Mg ha^{-1} per Mg.cm $ha^{-1}hr^{-1}$	<0.10 (1.0)	0.10-0.29 (0.8)	0.30-0.49 (0.5)	0.50-0.69 (0.3)	>0.70 (0.2)	4
Organic carbon (%)	<0.50 (0.2)	0.50-0.75 (0.3)	0.75-1.0 (0.5)	1.0-1.5 (0.8)	>1.5 (1.0)	3
N (kg ha^{-1})	<200 (0.2)	200-280 (0.3)	280-500 (0.5)	500-560 (0.8)	>560 (1.0)	3
P (kg ha^{-1})	<2.5 (0.2)	2.5-5.0 (0.3)	5.0-10.0 (0.5)	10.0-25 (0.8)	>25 (1.0)	3
K (kg ha^{-1})	<60 (0.2)	60-100 (0.3)	100-140 (0.5)	140-280 (0.8)	>280 (1.0)	3

Values in the parenthesis are converted score between 0 to 1, Model 3 (Asymmetric left): more is better, Model 4 (Asymmetric right): Less is better'.

$$MF(x_i) = \left[1 \Big/ \left(1 + \{ (x_i - b_2 + d_2) / d_2 \}^2 \right) \right] \text{ if } x_i > (b_2 - d_2) \quad (4)$$

Model parameters include lower crossover point (LCP), the central concept (*b*), upper crossover point (UCP), and width of transition zone (*d*) (Burrough et al., 1992). The soil parameters taking the model type were shown in Table 2.

Weights were assigned to the potential indicators that reflected their relative importance. The converted values on 0 to 1 scale were then multiplied by the weights assigned to them. Summing the values of the weighted parameters, a quantitative value SLTL indicating the state of soil was obtained for each soil mapping unit. A comprehensive guideline for the estimation of T values based on the favourable rooting depth was followed as per general guidelines for assigning soil loss tolerance "T" (USDA-NRCS, 1999). Soils having higher T-values are more resistant to erosion. In this way, for each soil sampling point, adjusted T values at cell/ polygon/pixel level were determined for different soil types and on a watershed basis with different land uses for better watershed planning and management and then weighted SLTL values were determined for a particular mapping class from all polygons belonging to that class for comparison with the potential soil loss.

After the determination of SI model parameters, the next step followed was to determine potential soil loss. In this study a combination of remote sensing, GIS, and RUSLE model (Renard et al., 1997) was used to estimate the soil erosion rate on a cell-by-cell/pixel basis. Revised Universal Soil Loss equation (RUSLE) is given as:

$$A = R \times K \times L \times S \times C \times P \quad (5)$$

where A is computed average soil erosion per unit area, expressed in the units selected for K and for the period selected for R (Mg ha^{-1}); R is a rainfall-runoff erosivity factor (Mg cm ha^{-1} h^{-1} per year); K is a soil erodibility factor ((Mg ha^{-1} per Mg cm ha^{-1} h^{-1}), L is slope length (m), S is the slope steepness (%); C is cover management factor and P is support practice factor. For determination of R-factor, available daily rainfall data from 1970-1985 for Bungidhar and Jaurasi raingauge stations, from 1970-2008 for Tamadhaun and Kedar rain gauge stations in the watershed were collected from Divisional Forest and Soil Conservation Office, Ranikhet. In the present study, the above relationship of determination of R-factor could not be used as continuous rainfall intensity data in the watershed were not available. Therefore, as an alternate approach relationship proposed by Ram et al. (1969) to determine daily EI_{30} values based on daily rainfall for Dehradun in the Garhwal foot hills was used which stated as:

$$Y = 3.1 + 0.533 X \quad (6)$$

where Y is the daily EI_{30} value in Mg-cm $ha^{-1}h^{-1}$ and X is the daily rainfall (mm) exceeding 12.5 mm. A point map of four rain gauge stations (Bungidhar, Jaurasi, Tamadhaun and Kedar) was prepared in ArcGIS 9.3 by locating it on mosaiced toposheets. Thiessen polygons were created by nearest point method in ArcView 3.2 software and then transferred to ArcGIS 9.3 for calculating area of each thiessen polygon. Thiessen polygon map with R-factor attribute was overlaid on soil mapping unit map and clipped individually for each Thiessen polygon using 'clip' option in GIS and R-factor for each polygon was derived and weighted R-factor was determined using following relationship.

$$R_w = \frac{\sum_{i=1}^{n} R_i \times A_i}{A} \quad (7)$$

where R_i is the calculated rainfall-runoff erosivity factor for i^{th} rain gauge station, A_i is the area of i^{th} Thiessen polygon and A is the total area of polygons. Daily rainfall-runoff erosivity (R) factors were determined for all the four rain gauge stations. Then annual erosivity factors were determined and iso-erodent map was generated for the watershed using IDW technique in ArcGIS. K- factor was determined using soil texture and organic matter content (Mandal et al., 2009) at each polygon level and then weighted K-factor was derived for each mapping class. Slope length was determined using ArcGIS by generating flow accumulation and flow length map by raster grid cumulation and maximum downhill slope method (Lu et al., 2004). Polygon-wise slope length and slope steepness was obtained from flow length map and slope map,

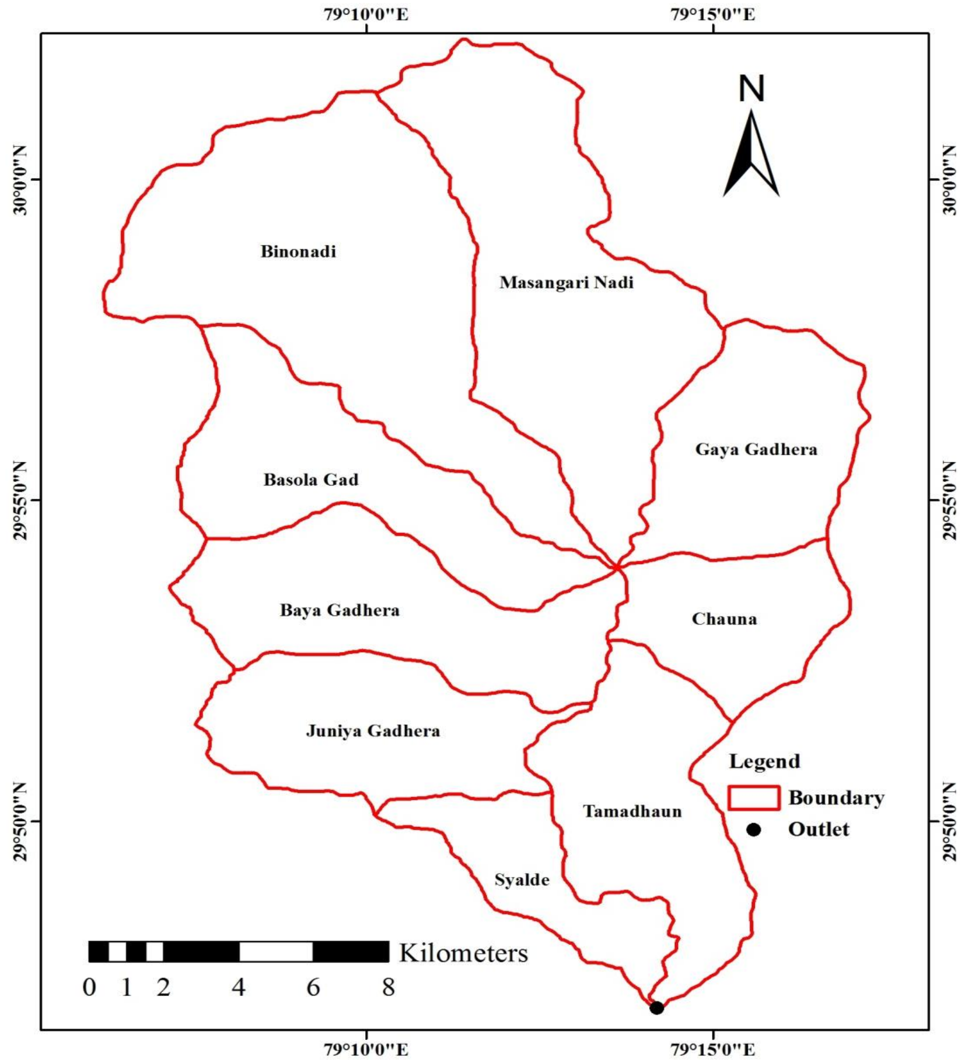

Figure 1. Delineated sub-watersheds of Bino watershed.

respectively. Both the maps were overlaid on soil mapping unit map to generate the polygon-wise and mapping class-wise L and S values. C and P values were taken from different literatures.

Computation of erosion tolerance index

To calculate the erosion tolerance index (ETI) for each mapping unit, the comparison was done between calculated annual soil loss rate (A) and soil loss tolerance level (T) in the form of T/A ratio. A unit having a T/A ratio less than 1.0, indicates that annual soil loss could exceed the tolerance level; hence indicating the vulnerability of the land. The ETI was then established using an asymmetric left fuzzy function. This function shows that T/A of 1.0 is selected as an ideal point, while 0.5 (soil loss exceeding two times the threshold value) is for LCP. The result was expressed in continuous values from 0 (high vulnerability) to 1.0 (almost no risk) (Baja et al., 2002). To determine ETI, T/A ratio was determined for each mapping class and for each sub-watershed. For each mapping class, ETI was determined by taking b_1 and d_1 as 1 and 0.5, respectively. Weighted ETI value was then calculated for each class and for each sub-watershed and used for prioritization of sub-watersheds.

RESULTS AND DISCUSSION

Thematic maps of the watershed

The delineated Bino watershed and its sub-watershed boundaries have been shown in Figure 1. Area and perimeter of the watershed were found to be 296.17 km^2 and 83.24 km, respectively. It was found from the digital elevation model (DEM) (Figure 2) that the elevation of the watershed varied from 802-2884 m above mean sea level (msl) and maximum area (38.15%) was under the elevation range of 1200-1400 m above msl, whereas the lowest 2.39% was under 2400-2884 m amsl. Area covered up to 2000 m above msl was 87.04%, whereas area up to 1600 m elevation was 64.24% of the total geographical area of the watershed. The generated slope map (Figure 3) through GIS showed that 49.22% area was covered under slope up to 35%, whereas 50.78% area was with more than 50% slope. Based on general slopes in

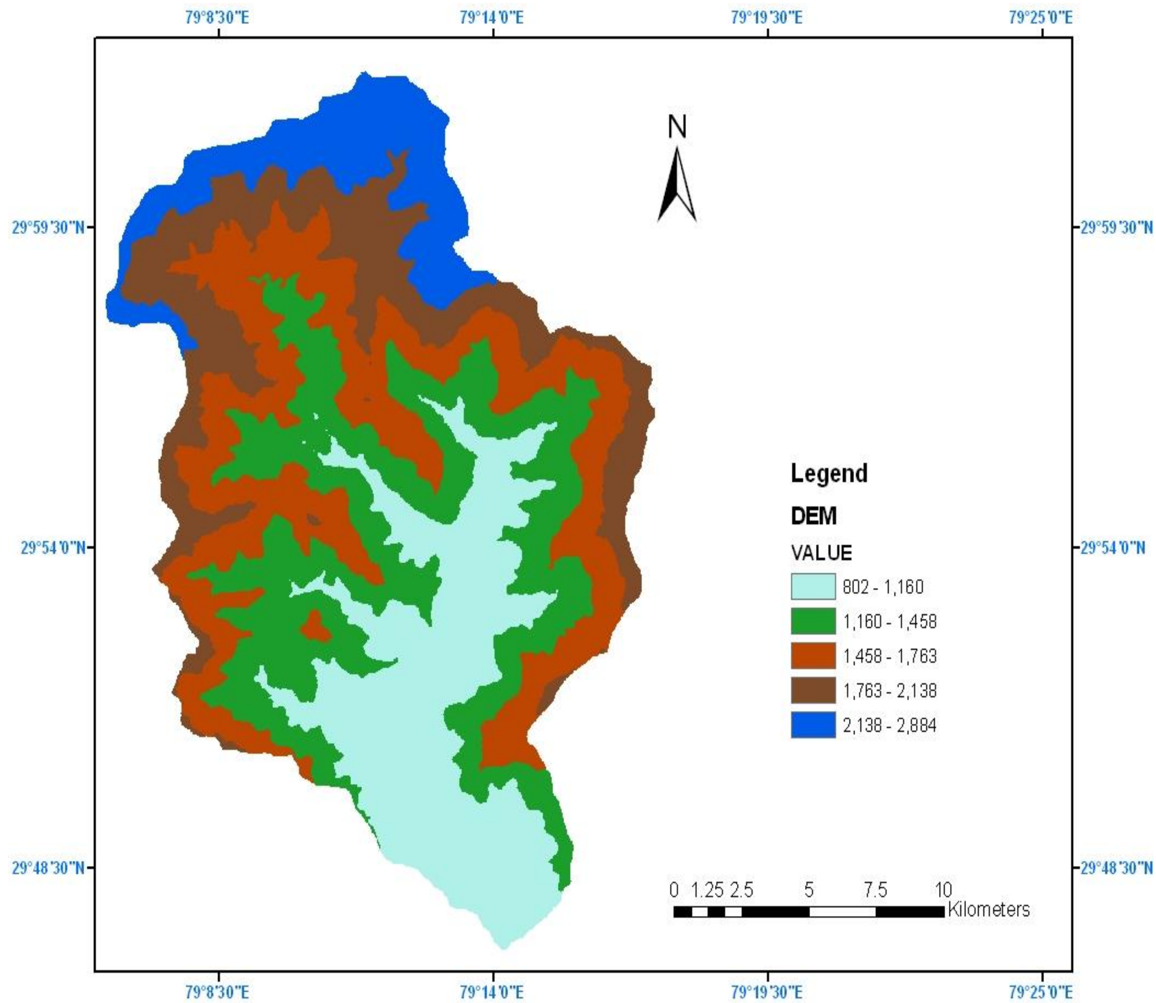

Figure 2. Digital elevation model of the Bino watershed.

different portions of watershed, the land may be categorized as a valley, moderate and steep hill areas. However, the study watershed belonged to steep slope category, as only 4% area was under mild slope (<10%). The soils had coarse textures (sandy loam, loam and sandy clay loam, stony) and with high erodibility.

From the land use map (Figure 4) developed from satellite imagery for the year 2006, it was found that area under dense forest, open forest, agriculture land, waste land and water body was 77.72 (26.24%), 69.49 (23.46%), 86.97 (29.37%), 58.52 (19.76%), and 3.47 (1.17%) km^2, respectively. Out of total agricultural land, 80.50 km^2 was rainfed and 6.47 km^2 irrigated.

Potential annual soil loss

The mean weighted annual rainfall determined from the Thiessen polygon developed for the watershed was found to be 931.3 mm. It was also observed that the rainfall-runoff erosivity factor for monsoon season (R_{mon}) and annual (R_{ann}) ranged from 272.52-498.07 and 390.8-624.72 Mg-cm $ha^{-1}h^{-1}$, respectively. K, LS, C and P-factor under different land uses in the watershed varied from 0.19-0.33 Mg ha^{-1} Mg^{-1} cm^{-1} ha h, 0.1-34.4, 0.001-0.34 and 0.13-1.0, respectively. On the basis of the obtained values of these factors, potential annual soil loss rate (A) for each mapping class and sub-watershed was determined by clipping sub-watershed boundary and was then compared with respective soil loss tolerance limit value (T). It was found that potential annual soil loss varied from 0.49-3.64, 1.93-18.83, 4.07-55.49 Mg ha^{-1} in the lower middle and higher slopes, respectively.

Quantification of SLTL in the study watershed

Soil samples were collected from each represent mapping class (Figure 5) and analyzed in the laboratory. The values of individual soil property representing each

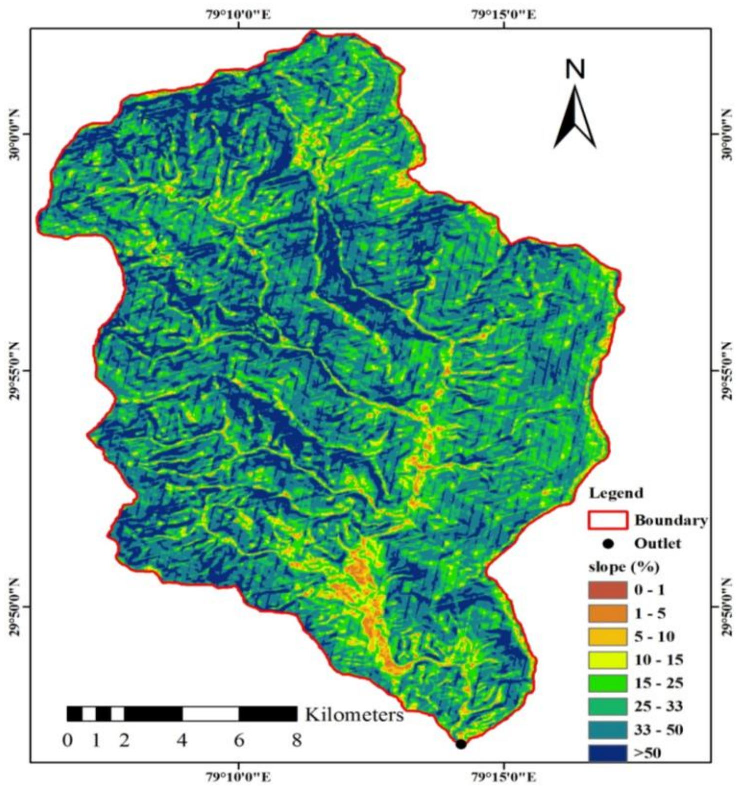

Figure 3. Slope map of the study watershed.

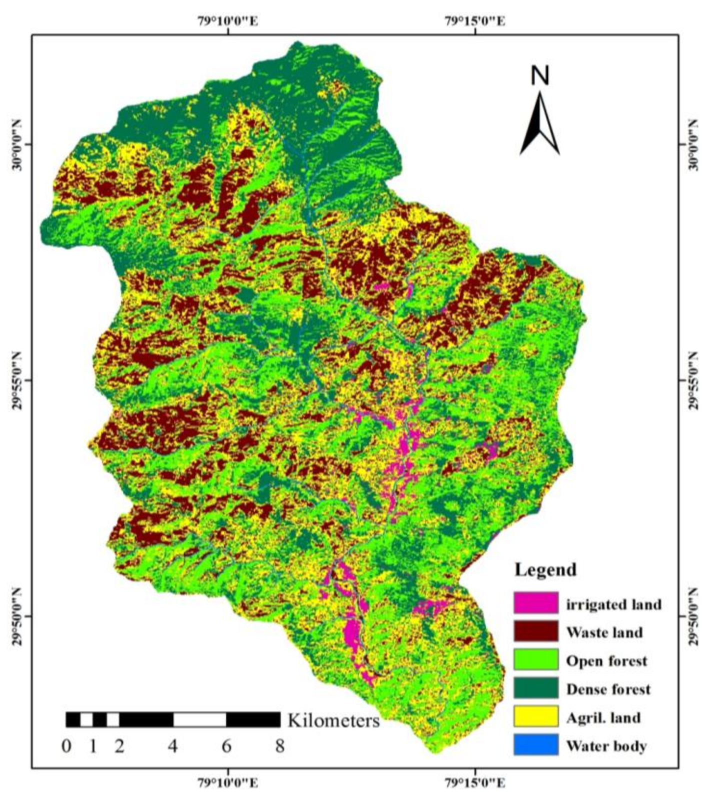

Figure 4. Land use map of the study watershed.

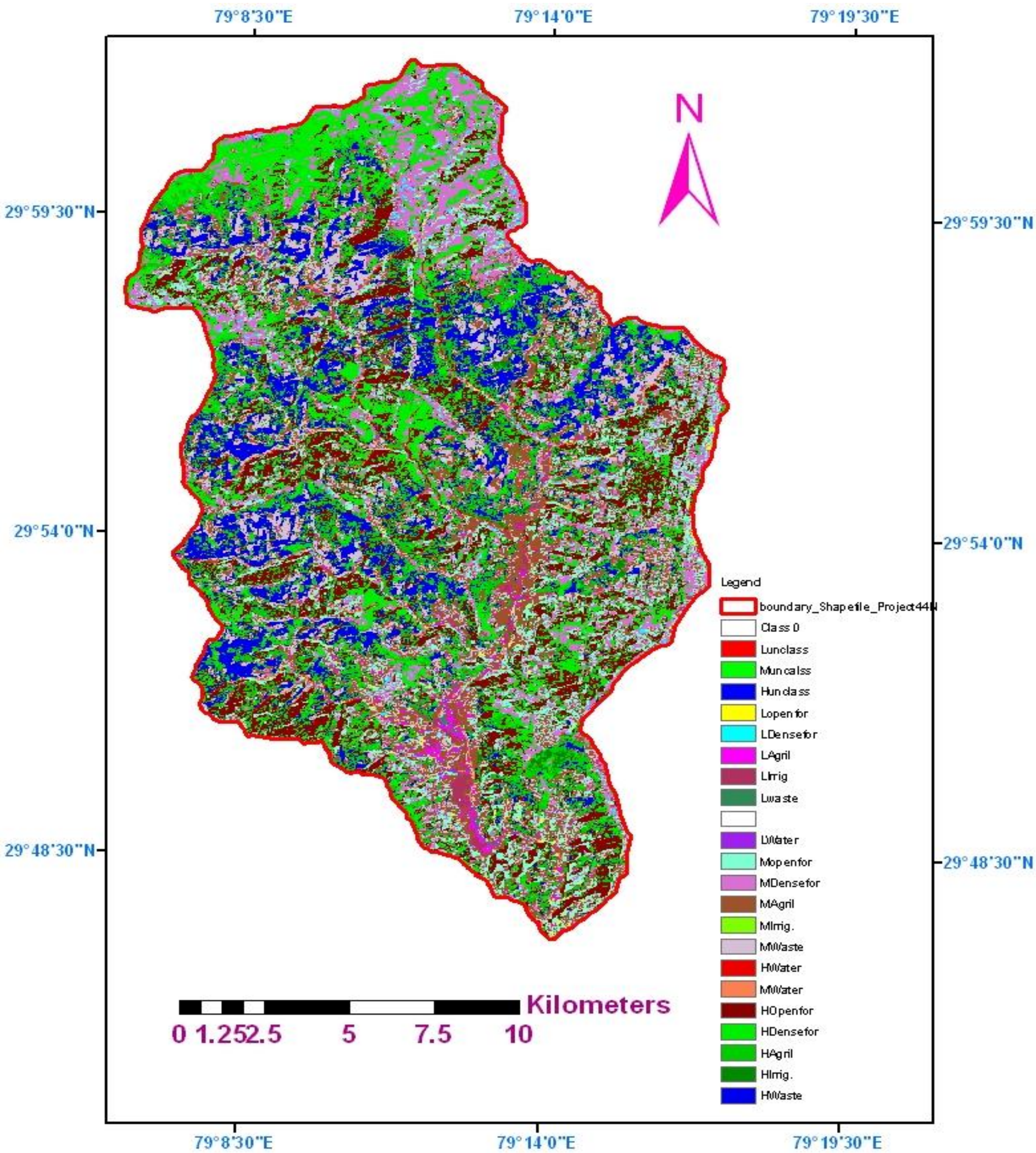

Figure 5. Soil mapping units in Bino watershed.

landuse were clubbed and their mean values were obtained. Soil textures found in the watershed include loam, silt loam, sandy loam and sandy clay loam in 0-15 cm solum depth, and loam, silt loam, sandy loam, sandy clay loam, loamy sand and clay loam in 15-30 cm solum depth. The values of pH ranged between 4.52 and 6.60 in 0-15 cm, and 4.66 and 6.71 in 15-30 cm solum depth which indicates that soils in the watershed are acidic in nature. The values of EC for the corresponding soil depths varied from 0.02-0.28 and 0.02-0.2 ds m^{-1}. Organic C content ranged from 0.66-2.31 in 0-15 cm and 0.61-2.27 in 15-30 cm depth. Available Nitrogen (N), Phosphorous (P), and Potassium (K) ranged from 37.63-240.14, 37.01-68.44, 69.58-669.14 kg ha^{-1} in 0-15 cm and from 25.1-225.79, 34-72.01, 50-328.22 kg ha^{-1} in 15-30 cm solum depth, respectively. The value of K-factor varied from 0.21-0.27 and organic C from 1.03-1.87. The organic matter, N, P, and K contents in dense forest were the highest indicating organic matter build up in the surface soil.

Soil groups were determined on the basis of aggregated scores (Table 2) by summing up the weighted scores of all the indicators which represent the level of resistance to erosion. The SLTL values of different soils were determined on the basis of soil group and soil depth. SLTL values for each polygon were determined and then weighted SLTL values for each landuse at a particular slope class were determined.

Table 2. Categorical ranking of soil attributes used in the study.

Soil attribute	Ordinal/categorical ranking					
	1	2	3	4	5	Model used
Saturated hydraulic conductivity (cm h^{-1})	<1.0 (0.2)	1.0-2.0 (0.3)	2.0-3.5 (0.5)	3.5-5.0 (0.8)	>5.0 (1.0)	3
Bulk density (Mg m^{-3})	<1.40(1.0)	1.4-1.47 (0.8)	1.48-1.55 (0.5)	1.56-1.62 (0.3)	>1.63 (0.2)	4
K-factor (Mg ha^{-1} per Mg.cm $ha^{-1}hr^{-1}$	<0.10 (1.0)	0.10-0.29 (0.8)	0.30-0.49 (0.5)	0.50-0.69 (0.3)	>0.70 (0.2)	4
Organic carbon (%)	<0.50 (0.2)	0.50-0.75 (0.3)	0.75-1.0 (0.5)	1.0-1.5 (0.8)	>1.5 (1.0)	3
N (kg ha^{-1})	<200 (0.2)	200-280 (0.3)	280-500 (0.5)	500-560 (0.8)	>560 (1.0)	3
P (kg ha^{-1})	<2.5 (0.2)	2.5-5.0 (0.3)	5.0-10.0 (0.5)	10.0-25 (0.8)	>25 (1.0)	3
K (kg ha^{-1})	<60 (0.2)	60-100 (0.3)	100-140 (0.5)	140-280 (0.8)	>280 (1.0)	3

Values in the parenthesis are converted score between 0 to 1, Model 3 (Asymmetric left): more is better, Model 4 (Asymmetric right): Less is better'.

It was observed from the calculated SLTL values that in the study watershed these values varied from 2.5-10 Mg ha^{-1} yr^{-1}. It was also found that SLTL values in the sub-watersheds varied from 3.1-10.0, 5.0-10.0 and 6.7-10.0 Mg ha^{-1} in the lower, middle and high slopes, respectively.

Erosion tolerance index (ETI) for sub-watersheds

For each sub-watershed, five land uses and three slope classes, 15 ETI values for all mapping classes (landuse units) were determined and thus, a total of 135 ETI values for the whole watershed were obtained. It was observed from data in Table 3 that in case of lower slope with open and dense forest, rain-fed and irrigated agricultural areas except waste land in the entire sub-watersheds annual soil loss rate was much lower than the soil loss tolerance limit, so no ETI values were considered. ETI values under waste land varied from 0.374-0.930. In middle slope, ETI values for the area under dense forest and irrigated agricultural land were also not considered as annual soil loss rate was much less than the soil loss tolerance limit.

In case of rain-fed agricultural land, open forest and waste land ETI values ranged from 0.160-0.222, 0.299-0.700 and 0.142-0.180, respectively. On higher slopes ETI values under open forest, dense forest, rain-fed agricultural land, irrigated agricultural land and waste land varied from 0.170-0.249, 0.439-1.0, 0.117-0.130, 0.216-0.389 and 0.121-0.137, respectively. The lowest ETI was in Bino sub-watershed, whereas the highest for Syalde sub-watershed in all lower, middle and higher slopes. In some areas of the watershed, annual soil loss rate was less and in some areas it was more than SLTL. Therefore, weighted ETI value was determined for each sub-watershed and it was found that the weighted ETI values for Basolagad, Baya Gadhera, Bino Nadi. Chauna, Gaya Gadhera, Juniya Gadhera, Masangari Nadi, Syalde and Tamadhaun sub-watersheds were 0.218, 0.232, 0.238, 0.238, 0.212, 0.337, 0.244, 0.380 and 0.353, respectively. These weighted ETI values were used for prioritization of sub-watersheds by taking the criteria more is the better model. The result of prioritization analysis revealed that the highest priority was given to Gaya Gadhera sub-watershed, second most priority to Basolagad and least priority to Syalde sub-watershed and prioritization map was shown in Figure 6.

DISCUSSION

Potential soil loss and soil loss tolerance limit values in lower, middle and higher slopes revealed that potential soil loss in lower slope was within the permissible limit, but middle and higher slopes may be treated with different conservation measures to bring soil loss within permissible limits in all the land uses except under dense forest and irrigated agricultural land in middle slope. The generally accepted maximum limit of soil loss (or T-value) is 11.2 Mg ha^{-1} yr^{-1} (Wischmeier and Smith, 1978), while Rubio (1986) considered a T-value of 20 Mg ha^{-1} yr^{-1}. In Northwestern Himalayas of India, T value varied from 5.0-12.5 Mg ha^{-1} yr^{-1}. When SLTL value for the study area was overlaid and clipped in GIS environment from the map developed by Mandal et al. (2009) for Uttarakhand state, it was found to be only a single value of 10 Mg ha^{-1} yr^{-1}. Because of the large grid size (10 × 10 km), this map failed

Table 3. Erosion tolerance indices (ETI) for different sub-watersheds.

Landuse unit	Sub-watersheds								
	Gayagadhera	**Bino**	**Tamadhaun**	**Syalde**	**Masangari**	**Juniyagadhera**	**Chauna**	**Bayagadhera**	**Basolagad**
L open	-	-	-	-	-	-	-	-	-
L dense	-	-	-	-	-	-	-	-	-
L agril	-	-	-	-	-	-	-	-	-
L irrigated	-	-	-	-	-	-	-	-	-
L waste	0.3936	0.3736	0.7272	0.9296	0.3748	0.8663	0.3971	0.5574	0.3822
M open	0.3118	0.2988	0.5286	0.7005	0.2996	0.6368	0.3141	0.4163	0.3044
M dense	-	-	-	-	-	-	-	-	-
M agril	0.1626	0.1599	0.1987	0.2227	0.1601	0.2139	0.1630	0.1814	0.1611
M irrigated	-	-	-	-	-	-	-	-	-
M waste	0.1439	0.1421	0.1663	0.1804	0.1422	0.1753	0.1441	0.1558	0.1429
H open	0.1732	0.1700	0.2181	0.2490	0.1702	0.2376	0.1738	0.1965	0.1714
H dense	0.4652	0.4388	0.8720	0.9998	0.4403	0.9801	0.4698	0.6784	0.4501
H agril	0.1178	0.1172	0.1253	0.1296	0.1172	0.1280	0.1179	0.1219	0.1175
H irrigated	0.2219	0.2157	0.3165	0.3890	0.2161	0.3616	0.2230	0.2691	0.2184
H waste	0.1218	0.1210	0.1313	0.1368	0.1211	0.1348	0.1219	0.1269	0.1214

Note: L, M and H represents lower, middle and higher slopes, respectively; open- open forest, dense- dense forest, agril.- rainfed agricultural land, irrigated- irrigated agricultural land, waste- waste land.

to provide SLTL values for each landuse and slope class. However, to make the landuse planning more effective, it was considered appropriate to determine and use localized SLTL values. Thus, localized values of SLTL were determined for each landuse to make location specific landuse planning which varied from 2.5-10 Mg ha^{-1} yr^{-1}.

It was also observed that within the soil group, SLTL values varied with soil depth. The SLTL values depend on many factors and varied from one set of conditions to another. An average soil loss of 5 Mg ha^{-1} yr^{-1} has been considered as the limit for shallow soils (Hudson, 1986). Lal (1985) observed that for shallow soils with root restrictive layers at 0.2 to 0.3 m depth, a T-value is set at 1 Mg ha^{-1} yr^{-1}. But in this study, for shallow (36-56 cm) soil depth in waste land as low as 2.5-5 Mg ha^{-1} yr^{-1} of SLTL values with a maximum potential soil loss of 20.32 Mg ha^{-1} yr^{-1} were observed and thus, needed to be protected on priority basis. The variations in soil groups and SLTL values were due to different levels of the most sensitive indicators, viz. saturated hydraulic conductivity, K-factor and organic carbon. Assignment of site specific SLTL values will be helpful in assessing the vulnerability of soil in the watershed after comparing with a potential soil loss.

It was observed that in middle slope the magnitude of ETI value was in the order of waste land<rain-fed agricultural land<open forest. This showed that in middle slope wasteland is more vulnerable to soil erosion compared to rain-fed agricultural land and open forest that means it needs greater attention. Whereas in higher slope the magnitude of ETI value was in order of rain-fed agricultural land<waste land<open forest<irrigated agricultural land<dense forest. This may be due to higher SLTL and less soil erosion in dense forest and irrigated agricultural land compared to other land uses. ETI values were lower in dense forest may be due to more organic matter content in the soil and so the SLTL value. It was also found that ETI value decreases with increase in slope gradient in all the land uses as it is obvious that higher slope is more vulnerable to soil erosion with less SLTL as soil depth is low. It was observed that ETI values for each land use in the Bino sub-watershed were at par with Masangari sub-watershed (Table 3). This could be due to the fact that both sub-watersheds

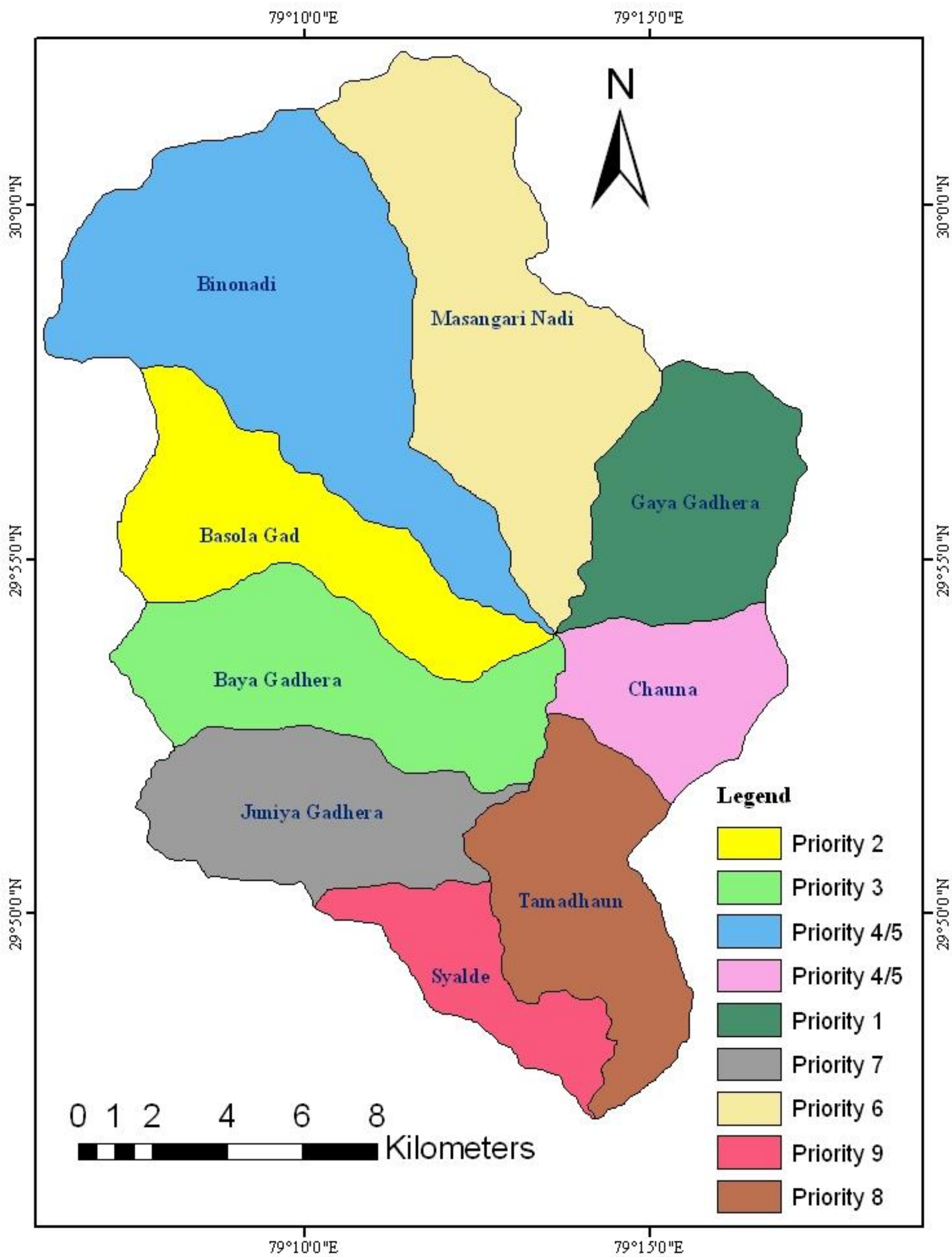

Figure 6. Prioritization map of sub-watersheds under study watershed.

were geo-morphologically similar. Again, the highest priority was given to Gaya Gadhera sub-watershed, whereas least to Syalde sub-watershed as per ETI values. Figure 1 showed that Gaya Gadhera sub-watershed is at a higher elevation and almost circular shaped compared to Syalde sub-watershed which is elongated one. This implies the higher soil erosion generation in Gaya gadhera sub-watershed compared to Syalde sub-watershed. Therefore, it corroborated the higher magnitudes of ETI value in Syalde sub-watershed.

The steep slopes of the area have caused soil erosion, resulting in the meager depth of topsoil and the prevalence of gravel and rocks in the surface and causing many exposed rocky areas, poor soil nutrition and lack of organic matter in the soils. There is a continued and ever increasing threat to productivity, food security and environmental quality, especially in ecologically sensitive eco-regions, characterized by fragile soil, high population density and harsh environment. The quantitative ETI values and prioritized map produced in this study may be used as the guide for the policy makers for examining and deciding what land use management practices and which sub-watershed should be adopted on priority on a given individual land units to reduce the degree of soil erosion up to the soil loss tolerance limit.

Conclusions

The main problem of the study area in Indian Himalaya was steep slopes and mismanagement of different land uses, particularly agricultural systems which are ploughed parallel to the slope direction. This problem led to the soil erosion as high as 80 Mg $ha^{-1}yr^{-1}$. Again worldwide the generally accepted maximum limit of soil loss is 11.2 Mg ha^{-1} yr^{-1}. Therefore, this paper presented the approaches to analyze potential soil loss and determining localized soil loss tolerance limit and showing their importance and effectiveness of ETI in watershed management planning. Implementation of watershed programs should target not only the reduction in erosion rate, but also reduction in the gap between the potential erosion rate and the soil loss tolerance rate in an area as soil loss tolerance level of all the soils is not the same. The methodological development followed a framework based on RUSLE model, fuzzy set analysis, remote sensing and GIS. The localized values of SLTL were found to be varying from 2.5-10 Mg ha^{-1} yr^{-1} for different land uses with maximum 55.4 Mg ha^{-1} yr^{-1} of potential soil erosion from rainfed agricultural land. It was found that ETI values ranged from 0.212-0.380 and the value decreases with increase in slope gradient in all the land uses as it is obvious that higher slope is more vulnerable to soil erosion with less SLTL as soil depth is low which proved the hypothesis of the study.

The ETI may be used as the basis for examining land use practices for adopting on a given land unit to maintain soil loss within a tolerable limit. The ETI values used for prioritization and results revealed that the highest priority was given to Gaya Gadhera sub-watershed and least to Syalde sub-watershed as per ETI values. The quantitative approach, produced in this study may serve as a guide for the policy makers to decide the use of land with different farming system models and landuse management practices. Use of the SLTL will improve conservation planning, help to meet erosion control regulations for development of sustainable watershed management in the study area as well as in this portion of India. Remote sensing and GIS technology can be used as an alternative to the conventional method of prioritization of sub-watersheds for implementing soil conservation practices. This study has provided a package of scientific knowledge that can be used to transfer the technology of land use management from the researcher to the user.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Sources of resistance in mungbean genotypes to *Cercospora* leaf spot disease and its management

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Sixty-five mungbean genotypes were screened for resistance against *Cercospora* leaf spot under disease epiphytotic condition. The disease symptoms initiated on the lower side of the old leaves of susceptible genotypes and progressively spread all over the plant. Considerable variations among the genotypes were observed with respect to disease reactions. Among the sixty-five genotypes, one genotype LGG-460 was found highly resistant while GM-02-08, GM-02-13 and GM-03-03 were categorized into resistant. However, fifty-two genotypes were found moderately resistant, while the rests of the genotypes were grouped into susceptible to highly susceptible. Minimum disease index (0.9) and Maximum disease control (70.1%) was recorded in the foliar application of Carbendazim (12%) + Mancozeb (63%) 75% WP at 0.2% concentration. However, Hexaconazole (5%) + Captan (70%) 75% WP and Mancozeb75%WP were also found statistically at par with 1.0 and 1.2 disease index and percent disease control were 61.3 and 62.7, respectively.

Key words: Mungbean, *Vigna radiata*, *Cercospora canescens*.

INTRODUCTION

Mungbean [*Vigna radiata* (L.)] is one of the important pulse crop of India. It is widely cultivated throughout the Asia including India, Pakistan, Bangladesh, Sri Lanka, Thailand, Cambodia, Vietnam, Indonesia, Malaysia and South China. Leaf spot disease caused by *Cercospora canescens* Ellis and Martin is a serious disease in the mungbean growing areas of the country where high humidity prevails during the growing season. The productivity of pulse crops became stagnant for the last three decades because of less success in developing

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improved varieties and moreover it is grown on marginal and sub marginal lands. Average yield of the crop is very low mainly due to low inherent yield potential and susceptibility of the crop to diseases (Thakur et al., 1977). *Cercospora* leaf spot is one of the important diseases that cause serious losses to mungbean crop and 23% losses in yield have been reported (Quebral and Cagampang, 1970). The disease starts appearing about 30 to 40 days after planting. Depending upon the temperature and humidity, it spreads rapidly in susceptible varieties causing premature defoliation and reduction in size of pods and grains (Grewal et al., 1980). Several workers had reported the effective control of the disease with the application of fungicides (Singh and Singh, 1978). The cheapest, practical and economical control of the disease can be achieved by the resistant source of the disease (Jadhav and Sharma, 1983). Therefore, it is necessary to develop resistant varieties to reduce the disease population and production cost as well as to protect the environment. The latest investigation on the sources of resistance is present need of the day.

MATERIALS AND METHODS

Evaluation of genotypes for resistance

Sixty-five mungbean genotypes obtained from Indian Institute of Pulse Research, Kanpur and Department of Plant Pathology, B. A. College of Agriculture Anand were screened against *Cercospora* leaf spot disease during the season *Kharif* 2011 and 2012 under disease epiphytotic condition. Each test entry was sown in a row of 5 m with 30 cm apart and 10 cm distance from plant to plant alone with variety IR 16 as susceptible check after every 5 test entries. This variety was confirmed to be highly susceptible to the disease during the previous seasons. Initial plant count was taken 10 to 15 days after sowing. The data on severities of *Cercospora* leaf spot on 10 randomly selected plants in each row were recorded. The severities were recorded before flowering, pod formation and at physiological maturity. The severity of disease assessing plant disease resistance reactions was recorded using an arbitrary scale 1 to 5 in terms of leaf coverage by *Cercospora* leaf spot (Park, 1978) where; 1= highly resistant, 2= resistant, 3= moderately resistant, 4= susceptible and 5= highly susceptible.

Management of *Cercospora* leaf spot disease

The experiment was conducted during *Kharif* 2011-12 and 2012-13 (Third week of July) at experimental site of Plant Pathology, B. A. College of Agriculture, Anand under disease epiphytotic condition. The susceptible variety IR 16 was sown in rows 30 cm apart and 10 cm distance from plant to plant in plot size of 5 x 3 m. The treatments were replicated thrice in a randomized block design (RBD). Standard agronomical practices were followed to raise the crop. Fungicides and botanicals were sprayed just after initiation of disease and repeated twice at 15 days interval. Plots without sprays served as check. Observations on disease reactions assessing disease development were recorded 7 days after last sprays of fungicides as well as botanicals using 0 to 5 grade (Kapadiya and Dhruj, 1999) where; 0: No spots on any of the leaf, plant green with dense foliage; 1: lesions affecting 1 to 5% of leaf surface and about 1 to 5% of the total foliage; 2: lesion usually dark brown affecting 6 to 10% of leaf surface and total foliage; 3: lesions affecting 11 to 30% of leaf surface and 11 to 35% of the total foliage; infection more severe on lower leaves; 4: lesions affecting 31 to 60% of leaf surface and about 35 to 70% of the total foliage; slight defoliation of the diseases leaves; 5: Numerous lesions covering 61 to 100% of leaf surface and 71 to 100% of the total foliage; defoliation advancing. Randomly selected five plants were assessed individually from each treatment and the mean disease index was calculated.

RESULTS AND DISCUSSION

The results presented in Table 1 showed considerable difference among the genotypes for the level of resistance against the disease. Out of sixty-five genotypes, one genotype LGG-460 was found highly resistance against the disease while GM-02-08, GM-02-13 and GM-03-03 were grouped as resistant. However, fifty-two genotypes were found moderately resistant, while seven genotypes viz. PDM-84-143, PDM-288, IPM-02-1, IPM -99-125, PDM-139, GM-02-04 and GM-03-10 were grouped into susceptible and the rest of the two genotypes, that is, IPM-02-3 RED and IR-16 were categorized into highly susceptible. The results corroborate with the earlier reports of Raje and Rao (2002) which screened 200 genotypes of mungbean against *Cercospora* leaf spot and reported 174 as resistant; whereas out of 100 diverse stock of mungbean, 18 genotypes were identified as resistant to the disease (Basandrai et al., 1999). Similarly, Haque et al. (1997) reported that twelve genotypes (NM-98, 98-cmg-003, C2/94-4-42, NM-1, NM-2, 98cmg-018, BRM-188, CO-3, Basanti, PDM-11, BARI Mung-2 and VC3960-88) with average disease score of “1”, were found highly resistant. On the basis of present investigations, it can be proposed that LGG-460 genotype identified as highly resistant may be exploited in the breeding programme aimed at the development of high level resistant variety of mungbean against *Cercospora* leaf spot.

The two year pooled analysis of data indicate that all fungicides as well as botanicals tested significantly reduced the disease as compared to untreated check (Table 2). Minimum disease index (0.9) and maximum disease control (70.1%) was recorded in the foliar application of Carbendazim (12%) + Mancozeb (63%) 75% WP at 0.2% concentration. However, Hexaconazole (5%) + Captan (70%) 75% WP and Mancozeb75%WP were also found statically at par with 1.0 and 1.2 disease index and percent disease control were 61.3 and 62.7 respectively. Among botanicals, satisfactory results were not obtained from any of the three botanicals tested. Copper oxychloride 50% WG, Chlorothalonil 75% WP and Propineb 70%WP gave moderate effectiveness against the disease and were statically at par with each other with 1.7, 1.8 and 1.9 disease index and 45.2, 41.5 and 44.5% disease control respectively. The highest mean yield of 9.9 Q/ha was recorded in Carbendazim (12%) + Mancozeb (63%) 75%WP followed by

Table 1. Reaction of mungbean genotypes against *Cercospora* leaf spot under disease epiphytotic condition during season (Mean data *kharif*- 2011 and 2012).

Disease grade	Disease reaction	Number of genotypes	Genotypes
1	Highly resistant	1	LGG-460
2	Resistant	3	GM-02-08, GM-02-13 and GM-03-03
3	Moderately resistant	52	PDM-262, PDM-11, PDM-87, IPM-02-14, BRS-2435, GM-9926, TMV-37, SAPTARI LOCAL, K-851, MEHA, GM-3, GM-4, GM-9703, GM-9705, GM-9917, GM-9918, GM-9925, GM-9926, GM-2K-5, GM-2K-14, GM-02-01, GM-02-02, GM-02-03, GM-02-05, GM-02-06, GM-02-07, GM-02-09, GM-02-10, GM-02-11, GM-02-12, GM-02-14, GM-02-15, GM-02-16, GM-02-17, GM-02-18, GM-02-19, GM-02-20, GM-02-21, GM-03-01, GM-03-02, GM-03-04, GM-03-05, GM-03-06, GM-03-07, GM-03-08, GM-03-09, GM-03-11, GM-03-12, GM-03-13, GM-03-14, GM-03-15 and GM-03-16
4	Susceptible	7	PDM-84-143, PDM-288, IPM-02-1, IPM -99-125, PDM-139, GM-02-04 and GM-03-10
5	Highly susceptible	2	IPM-02-3 RED and IR-16

Table 2. Field evaluation of different fungicides and botanicals against *Cercospora* leaf spot of mungbean in disease epiphytotic conditions

Treatments	Concentration (%)	Mean disease intensity		Pooled	Disease control (%)	Mean yield (Q/ha)		Pooled
		2010-11	2011-12			2010-11	2011-12	
T_1: Propineb 70%WP	0.30	1.9	1.8	1.9^{bc}	44.5	8.2	8.3	8.2^{bc}
T_2: Carbendazim (12%) + Mancozeb (63%)75 %WP	0.20	1.0	0.9	0.9^{a}	70.1	9.8	9.9	9.9^{a}
T_3: Copper Oxychloride 50% WG	0.24	1.7	1.6	1.7^{b}	45.2	7.5	7.7	7.6^{b}
T_4: Chlorothalonil 75% WP	0.2	1.8	1.7	1.8^{bc}	41.5	6.2	6.7	6.4^{bc}
T_5: Hexaconazole (5%) + Captan (70%) 75% WP	0.05	1.0	0.9	1.0^{ab}	61.3	9.6	9.8	9.7^{ab}
T_6: Mancozeb 75%WP	0.20	1.2	1.1	1.2^{ab}	62.7	9.4	9.7	9.5^{ab}
T_7: *Azadirachta indica*	10	2.4	2.2	2.3^{c}	25.4	6.3	6.3	6.3^{bc}
T_8:*Datura stramonium*	10	2.4	2.3	2.4^{cd}	22.3	5.9	6.1	6.0^{c}
T_9:*Catharanthus roseus*	10	2.7	2.6	2.6^{cd}	16.4	5.5	5.8	5.7^{cd}
T_{10}: Untreated check	--	3.4	2.8	3.1	--	5.1	5.7	5.4^{cd}
S.Em±	--	0.18	0.14	0.15	--	0.69	0.71	0.70
C.D. at 5%	--	0.37	0.29	0.32	--	1.45	1.49	1.46
C.V. %	--	11.13	9.51	10.61	--	11.57	11.50	11.42

Treatments are analysis with three replications. Treatments means with letter(s) in common are at par by DNMRT.

Hexaconazole (5%) + Captan (70%) 75% WP and Mancozeb75%WP with 9.7 and 9.5 Q/ha respectively (Table 2).

The results are in agreement with the earlier findings of Kapadiya and Dhruj (1999) which reported minimum disease intensity (36.4%) and maximum disease control (61.0%) in application of 0.0125% difenconazole while, Carbendazim and Mancozeb gave significantly results reducing the disease as compared to untreated check. These findings are supported by the results of Gangopadhyay et al. (1996) too for the management of *Cercospora* leaf spot of groundnut. In the present study, new combination of molecules viz. Carbendazim (12%) + Mancozeb (63%) 75%WP and Hexaconazole (5%) + Captan (70%) 75% WP were found superior as compared to rest of the single molecules used in the study.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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