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The underway to pragmatic implementations of sustainable and intensive agricultural systems in Tanzania

Msafiri Yusuph Mkonda

Department of Geography and Environmental Studies, Solomon Mahlangu College of Science and Education, Sokoine University of Agriculture, Morogoro, Tanzania

A R T I C L E I N F O

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A B S T R A C T

For the past five decades, Tanzanian has regarded agriculture as a lead sector to economic development. However, more than 70% of the agricultural production has been for subsistence due to weak economic and technological investments. This happens despite the establishment of numerous programs, plans and initiatives to limit the problem. Therefore, there is an increased need to assess some important aspects of agro-ecosystems such as climate, soil and crops as significant factors for determining yields potentials in Tanzania. This approach is particularly important in the fifth term of Tanzanian government (2015–2025) which devotes serious efforts to transform the country to a middle income economy by 2025, whereas, industrial sector will be the key engine to capture this objective. In doing so, crop and climate data were collected from the Ministry of Agriculture and Tanzania Meteorological Agency. Microsoft excel and Theme content were the major methods for data analyses. Although there has been a slight increase in land expansion for crop production, the results exhibit that the overall agricultural trend (tn/ha) has been fluctuating at a declining trend. This yield decline has been significantly caused by rainfall climate change and soil infertility. This scenario is evidenced by the fact that the maximum potential photosynthetic yields in the study area is around 3–5 Mg/ha while that of the developed countries is 160 Mg/ha (10^{-6} Mg/g). Therefore, stoichiometric of fertilizer, rain water harvest or/and artificial rainfall, exploitation of ground water for irrigation, proper mapping or review of soil characteristics based on agro-ecological zones, proper breeding of various crops, intensive investments of finance and technology in agriculture should be adopted to maximize yields in the country.

1. Introduction

Sustainable intensification of agriculture is very crucial aspect in increasing yields to meet the demands for food security and raw materials. On top of that, food security is high on the global policy agenda. According to Garnett et al. (2013) the demand for food is increasing as populations grow and gain wealth to purchase more varied and resource-intensive diets. This has in turn increased the competition for land, water, energy, and other inputs into food production (Donald et al., 2001). In various countries the need to increase yields has significantly amplified the concerns for sustainable intensification in agriculture. China, Australia, Western Europe and Northern America are among the regions that have significantly intensified their agriculture sector while sub-Saharan Africa and Latin America have the least development on this aspect.

Although it is a bit difficult to articulate a more sophisticated definition of sustainable intensification, its underlying premised can give details. These premised include (i) the need to increase production, (ii) increased production must be met through higher yields because increasing the area of land in agriculture carries major environmental costs, (iii) food security requires as much attention to increasing environmental sustainability as to raising productivity, and (iv) it denotes a goal but does not specify a priori how it should be attained or which agricultural techniques to deploy (Tilman et al., 2002; Vitousek et al., 2009). This means, every country can intensify its agriculture based on the available resources, technology and land use change. The main reason here being to increase yields.

It is a fact that land use change is bringing serious consequences for biodiversity. The role of agriculture in the future will be crucial, as it has to support an ever-growing population. In the specific case of Africa, in the midst of a demographic transition, population growth is expected to be the highest on any continent by the year 2100 (Garnett et al., 2013).

In Tanzania, the needs for intensification of agriculture sector has significantly accrued due to increasing demands for food and raw materials. Climate, soil and crop are the major factors that determine the potentials of crop yields (Rowhani et al., 2011; Mkonda and He 2018a).

E-mail address: msamkonda81@yahoo.co.uk.

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Climate factor mainly encompasses the quantity and distribution of rainfall and temperature (Monfreda et al., 2009; Trajkovic 2005) while soil factor involves important aspect such as organic matter, structure, texture, drainage, cation exchange and topography just to mention a few. On the other hand, crop species, seed quality, evapotranspiration, planting date and harvest efficiency comprises the crop factor.

While these scientific factors are *ceteris paribus,* most developing countries have a wide range of constraints, e.g. weak economy, technology and infrastructure that impede agricultural production. Tanzania has over 70% of the people who entirely involve in agriculture (URT, 2005, 2007) thus, it is understandable that addressing these constraints would improve crop yields and economic development to majority citizens. Since 1980s, the country has not directly involved in agricultural production (URT 2005), rather it has tried to create favorable condition to farmers through formulation of friendly policies, plans, and programs to enable implementations of various agricultural activities. Indeed, it provides extension services and other related expertise in the production process. However, the mentioned constraints have remained the main stressors.

Various studies have been established to explore the agricultural status in the country (Bell et al., 2015; Ahmed et al., 2011). Most of these studies identify that having numerous agricultural constraints in the country is the major factor that devastate agricultural production. They have mostly mentioned shortage of capital, technology and infrastructure, reliance of rain-fed in the era of climate change diseases, pest, research, weak institutional framework, and donor dependency projects as the key barriers for the sector to progress.

However, despite this knowledge establishment, agriculture has remained a weak sector with dwindling yields. Despite the adoption of some initiatives through programs, projects and plans, however, little has been achieved. Since adaptation of agro-ecosystems to environmental stress is subject to local conditions comprising biophysical constraints, socioeconomic dynamics, and localized future climate scenarios (Thornton et al., 2009; Ahmed et al., 2011; Mkonda and He 2017a), it is advisable to improve farmers' resilience from local level.

A study by Paavola (2008) focused on few aspects that impede agricultural production in the country. In addition, other studies have earmarked either on a single crop versus climate, soil, or/and a certain agricultural system. Despite of their novelty and rigorous, these studies have however suffered numerous shortcomings on addressing the holistic challenges that largely impede the production process (Ahmed et al., 2011; Rowhani et al., 2011; Kimaro et al., 2015). On that basis, there is a need to establish an empirical study which is holistic in nature that encompasses soils, climate as important aspects in intensifying crop yields at both local and national levels.

While needing to assess the level of livelihood dependence on agriculture, the study by Mkonda and He (2017b) highlighted the percentage of utility among the major food crops produced in the sub-region of the country.

Despite of climate, soil and crop being the major factors that determine potential crop yields, it is understandable that local farmers are on the disadvantage side to cope or heal of their vulnerability as expressed by Eriksen and Noes (2003) in Table 2 below.

Here, appropriate technology, knowledge, institutions and management of resources are the best instruments underway to sustainable agricultural production. Some of these instruments are addressed in

Table 1
Percentage of utility among the key crops in Tanzania.

Crop	Food	Cash	Food &Cash	Total (%)
Millet	75	1.3	23.7	100
Maize	80	0	20	100
Sorghum	75	5	20	100
Average (n = 80)	76.6	2.1	21.3	100

Source: Modified from Mkonda (2014) (see Table 1).

Table 2
Examples of factors that influence vulnerability of the farmers.

Institutional Factors	Economic Factors	Environmental Factors
i. Informal skills ii. Local knowledge iii. Formal education, skills and technology iv. Informal network v. Formal security network vi. Strength of local institutions	i. Labour ii. Health iii. Access to natural resources iv. Access to Access to communal resources v. Access to alternative economic opportunities	i. Risk Environment ii. Degraded environment iii. High dependence of climate sensitive sectors and natural resources iv. Communal lands and resources

Source: Modified from Eriksen and Noes (2003).

Agricultural, National adaptation Plan of and other allied plans and initiatives of Tanzanian government. Among the underlying reasons for increased vulnerability of the farmers is that most of these farmers are economically destitute as they spend less than 2 $ a day (World Bank, 2015; URT 2015).

Such vulnerability imposes complex situation to addressing the same through agro-ecosystems (Mkonda and He 2017c). It is evident that soil factor, water shortage, inappropriate farming systems and unsuitable crop breeding are among the factors that exacerbate the situation. To lessen such complexity, a holistic approach is needed to overhaul the devastated agro-ecosystems. Additionally, maize comprises more than 70% of the food security however, it has already been affected by climate change and other environmental stress, and thus bringing insufficient yields from the crop.

The study on the correlation between climate and maize yields trends has been established as seen in Fig. 1 below. In addition, various organization and agricultural research institutions such as KATRINA, Ukiriguru, Naliendele and Ilonga, just to mention a few, have been developing new and tolerant crop breeds that could cope with the harsh weather. The developed new breeds encompasses both food and cash crops. In the midst of this, there is inappropriateness on the recent soil data information across the country. This is because land use change have significant contribution on the alterations of biological, physical and chemical properties of the soil. This therefore, may affect the stoichiometric of fertilizers in the soil and thus, the balance of important soil nutrients required by plants may be seriously distorted. Now that, even the advocacy of the use of biological, manure or/and chemical fertilizers may be misled.

Monoculture or single cropping is a main agricultural system in Tanzania. Maize cropping is predominantly produced in most upland areas while paddy is produced in lowlands. For ages, this monoculture has been in practice, however, excessive soil exhaustion has been a barrier for this system which thus, has been yielding little harvests. Scientifically, this has in turn been the major cause of nutrient deficiency in the soil due to imbalance between fertilizer input and output.

While the knowledge of nutrient deficiency in soil is understandable, there are limited evidences that this deficiency has been addressed especially through various soil management practices. This particularly refers to the thorough assessment of required nutrients for crop production. In some incidences, the ratio of nitrogen and carbon in the soil is imbalanced. We would least 1: 30 ratio, however, in some incidences carbon exceed nitrogen, thus, instead of sparingly assessing on this issue, some extension officers advise farmers without this specification as they provide general advice. This has significantly affected crop yields even though the actual quantity may be difficult to establish. Therefore, the science of soil nutrient assessment should be adhered for optimal yields.

Likewise, irrigation systems in Tanzania is well established. Reports from the government and international organizations have considerably exhibited this situation. Only 4% of the irrigable land has been harnessed (URT 2005), this indicates that the progression of intensive agriculture in the country is very insignificant. Besides, most

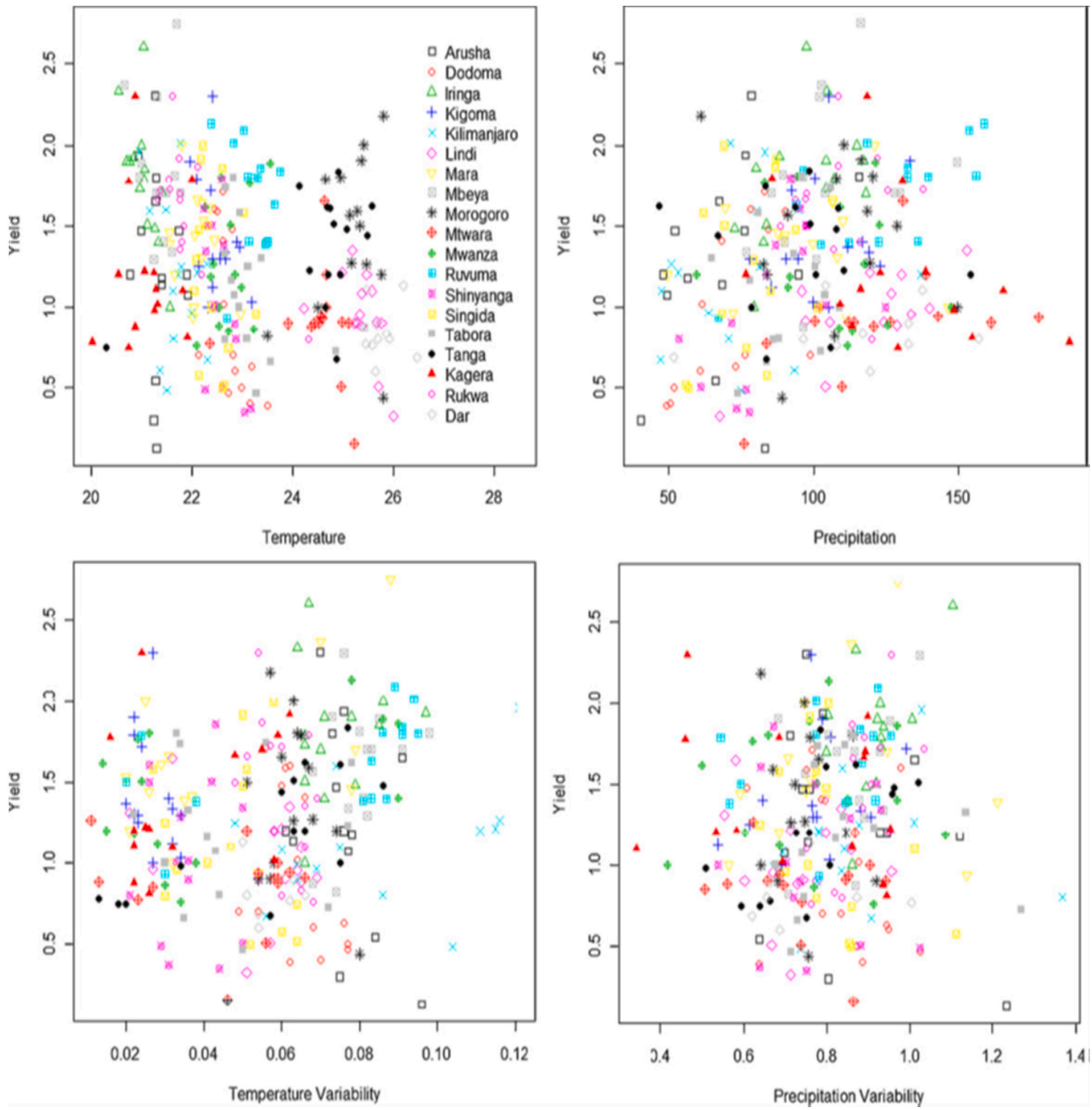

Fig. 1. Maize yields and the various climate factors used in this study. Scatterplots showing the relationships between maize yields and the various climate factors used in this study. Temperature is measured in mean seasonal ˚C and precipitation is shown in mean mm/month whereas maize yields are represented in tons/ha. Climate variability is measured using the coefficient of variation over the growing season. **Source**: Modified from Rowhani et al., (2011).

researchers, government officers and other agricultural practitioners regard this agricultural failure as part of business as usual, thus, no significant and tangible steps have been put in place. Unfortunately, some politicians use this verge as their political capital in the campaign. This is because we are still in the age where *trial and error* is still a way of doing things. If this is not, a serious approach should have been adopted in agricultural intensification to zero down this allegation.

Although the science on the influence of climate and soils to yields has been extensively and intensively explained in Tanzania, the interpretation of this science into practice has been a major challenges (Rowhani et al., 2011; Monfreda et al., 2009). This interpretation has been extremely difficult especially when dealing with heterogeneous situation (eight agro-ecological zones). In addition, there is a need to make an actual investigation, i.e. magnitude, of the actual constraints in each agro-ecological zone in order to ascertain the varied requirements. Thus, the best and holistic study should be established on the aspects of soil, climate and yield synergies to improve and sustain crop yields and resilience of the livelihoods. The present study aims to assess the climate, soil and crop factors and establish a sustainable agro-ecosystems based on those factors to improve crop yields. In addition, a careful review of the major constraints impeding agricultural sector will be done. The study also recommends some agricultural intensification approaches to optimize yields.

2. Materials and methods

2.1. Study profile

Tanzania is located on the eastern coast of Africa, south of the equator between latitudes 1° 00′ S and 11° 48′ S and longitudes 29° 30′ E and 39°45'. It borders the Indian Ocean to the east, Uganda and Kenya to the north, Burundi, Rwanda and the Democratic Republic of Congo to the west, and Mozambique, Zambia and Malawi to the south. Its total land area is 945 087 km^2. Agricultural land accounts for about 40% of the total land area and 30% is reserve areas i.e. national parks, game reserves and game controlled areas (URT, 2007). An estimated 55% of the land in the United Republic of Tanzania could be used for agriculture, and more than 51% for pasture.

Specifically, Tanzania has about 44 million hectares of land potential for agriculture but less than 24% of this potential is harnessed. Subsequently, shifting cultivation practices in various areas is the major cause of deforestation and land degradation on pastoral land (URT 2005). Tanzania experiences temporal and spatial rainfall variability (Agrawala et al., 2003; Ahmed et al., 2011; Rowhani et al., 2011). Ecologically, Tanzania has seven agro-ecological zones. These includes: Coastal; Eastern plateau and mountain blocks; Southern highlands; Northern Highlands/Northern rift valley and volcanic high lands, Arid Lands/Central plateau; Alluvial Plains/Rukwa-Ruaha rift zone; and Semi-arid lands/inland sedimentary plateau (FAO, 2007).

In terms of agricultural systems, Tanzanian agriculture is dominated by monoculture. Smallholder farmers form more than 70% of the participants in the sector (URT 2005). They are principally practicing extensive farming. Literally, intensive agriculture is not yet in place whereas only 4% of irrigable arable land is harnessed with less (9 kg per hectare) chemical fertilization (URT 2005).

2.2. Climate

In terms of climate; Tanzania has varied weather and climate according to season and place. Average temperature ranges between 17 °C and 27 °C, depending on location. The hottest period spreads between November and February (25 °C - 31 °C) while the coldest period occurs between May and August (15 °C - 20 °C). The mean annual rainfall varies considerably from place to place ranging from less than 400 mm to over 2500 mm per annum. Rainfall in about 75% of the country is erratic and only 21% of the country can expect an annual rainfall of more than 750 mm with a 90% probability. Rainfall is predicted to increase in areas with bimodal rainfall while decreasing in areas with unimodal rainfall (Adger 2006; Adger, 2006; Ahmed et al., 2011).

2.3. Soil

In terms of soil characteristics, Tanzania has different types and groups of soils which the normal peoples identify them as clay, loam and sand. However, Tanzania adopted the World Reference Base of Soil Resource as the system of nomenclature and correlation (URT, 2007). According to WRB Tanzania has 19 dominant soil types and they are grouped into two groups namely; organic soil and mineral soils (Partey et al., 2011; URT, 2007). The structure, concepts and definitions of the WRB are strongly influenced by (the philosophy behind and experience gained with) the FAO-UNESCO Soil Classification System.

2.4. Data collection and analyses

This study is broad to represent various areas (agro-ecological zones) of the country. Overall, it employed numerous methods in data collection and analyses.

2.4.1. Data collection

In this study, yield data for maize, paddy, sorghum, beans, cassava, millet and banana from 1996 to 2020 were collected from the Ministry of Agriculture (more especially from statistic unit and inputs section) from June to September 2020. These data were extracted from the archives of the ministry and through structured interviews with agricultural officials. In addition, documentary search were also employed in the data collection process. This review also focused on the policies, plans, vision and initiative that belong to the Ministry of Agriculture and allied sectors.

Then, these data were organized to get the total yields per crop and the yields in tons per hectare (tn/ha). Besides, the temporal data for land use changes were gathered from the Ministry of Agriculture too. Then, the data were subsequently plotted in figures and tables.

On the other hand, climate data (rainfall and temperature) from 1985 to 2020 were collected from Tanzania Meteorological Agency. This agency is a reliable and tangible source of climate data in the country. More so, soil data were retrieved from various sources of literature. Although the country has diverse soil types with varied characteristics, the retrieved data were from different representative sources.

2.4.2. Data analyses

Quantitative data from crop yields, climate (i.e. rainfall and temperature), and farmland were analyzed through Microsoft excel while qualitative data from structured interviews were thematically analyzed. The results from these quantitative analyzes were presented into figures and tables while that from qualitative analyses were inserted in the text during discussion. Soil data were presented in a table.

3. Results

3.1. Climate

As confirmed by IPCC (2014), Tanzania is among the country with high inter-annual and climate variability. This is evidenced by high inconsistency of both onset and cessation of rains. Fig. 2 indicates that rainfall and temperature have been slightly declining and increasing, respectively. Rainfall has been declining at a coefficient (r^2) of 0.11 while temperature has slightly increased at a coefficient of 0.14. So far these findings are in agreement with different studies such as those by Paavola (2008), Ahmed et al. (2011) and Rowhani et al. (2011), just to mention a few.

3.2. Soils

Assessment of soil nutrient is very important in determining the deficit required to be added or the excess that need to be reduced. Tanzanian soils are heterogeneous in nature as seen in Table 3 below. Scientifically, different soil types have differential natural endowment of nutrients. Among the significant nutrients are carbon (C), nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca). Their availability are determined by soil organic matter, soil texture and structure, cation exchange capacity, base saturation, topography, temperature, tillage and drainage just to mention a few. Biological fixation, animal manure and chemical fertilizers can add or catalyze the ingredients and functioning of these nutrients.

Despite of the scientific guidance that different crops, soil, climate and hydrological situation need different soil nutrients, it is evident that, there is high generalization of the chemical fertilizations. It is descendible that there are some fertilizers rich in NH_4 which work appropriate in water logged areas but are applied in dry areas. The vice versa is true with NO_3 which is recommendable in dry areas but is sometimes applied in water logged areas. Therefore, such inappropriateness brings significant negative impacts to both crop yields and soils.

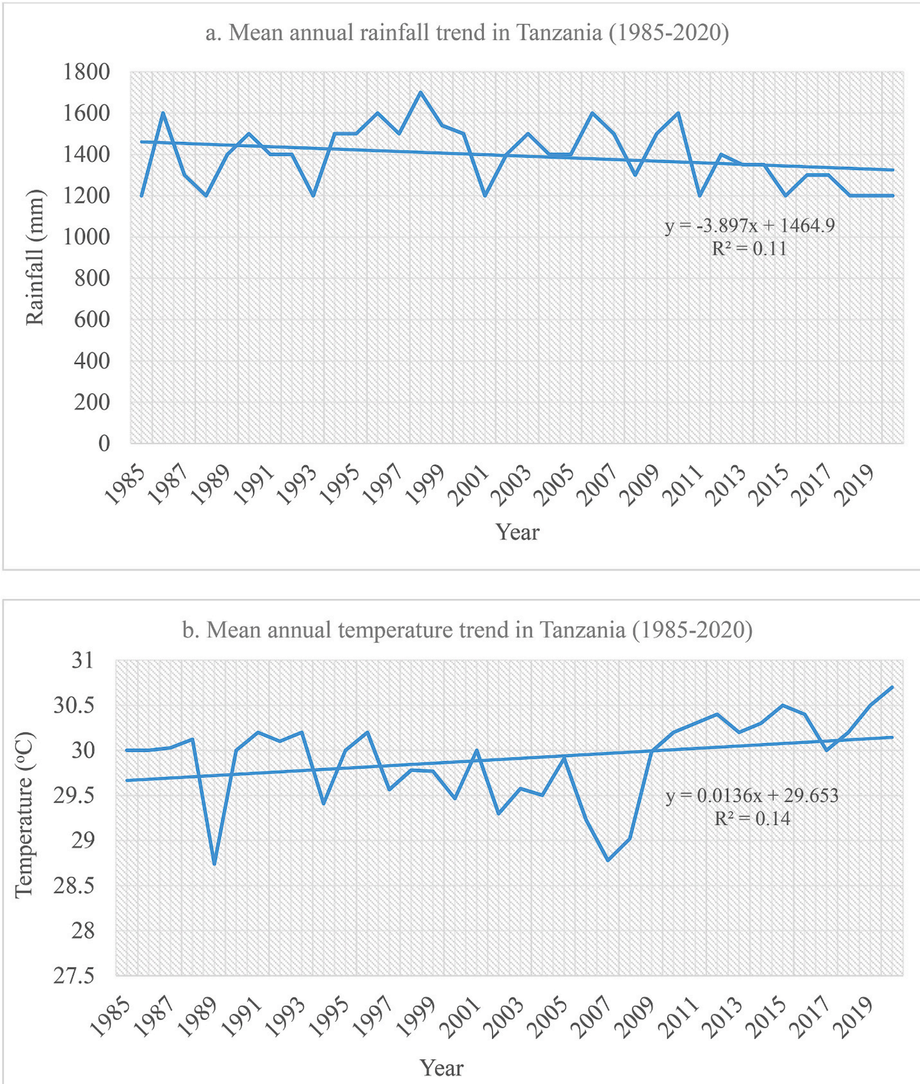

Fig. 2. Trend of mean annual rainfall (a) and temperature (b) in Tanzania from 1980 to 2017. **Source:** Field Survey.

Table 3
Main physiographic units and soils in Tanzania.

Physiographic units	Altitude (m.a.s.l)	Lithology	Dominant Major Soils
Mountains	>2000	mainly Precambrian gneiss	Leptosols, Ferralsols Luvisols, Phaeozems
Uplands	200–2000	Acid and intermediate Metamorphic rocks	Luvisols, Ferralsols, Cambisols, Arenosols
Coastal	0–200	Neogene and Quaternary Limestone and Sandstone	Fluvisols, Vertisols, Gleysols, Solonchaks
Alluvial plains	0–200	Unconsolidated materials	Fluvisols, Gleysols, Vertsols, Solonchaks

Source: FAO-UNESCO, 1988.

3.3. Crops

Major food crops such as maize, sorghum, millet, paddy and cassava, just to mention a few, are the major determinants of food security in Tanzania. Maize is a staple food to more than 70% of the Tanzanian people and thus, it has significant contribution to the national food security (URT, 2014). Statistics indicate that overall, there has been an increase in crop yields, however, this has been attributed by expansion of farm lands (Table 4).

The area under crop production has been increasing over time due to increase in population and needs to increase yields. The increase in area under farmland also reflects the desire to meet the demands for food security and raw materials. However, to get the actual increase in yields we need to us the tons per hectare (tn/ha) to reflect the potential yields of the area. In addition, farm expansion has been done due to the fact that most lands have infertile soil.

Actually, the production of tons per hectare has been unpredictable but in most cases has been fluctuating in a declining trend. Now that, the obtained yields have never been sustainable for food security due to increased food demands at both local to national levels. This imbalance necessitates to think twice on how to curb the situation. Refraining from this verge will increase the magnitude of the problem.

In this analysis, Figs. 3 and 4 below indicate the production trends of

Table 4
Area under crop production in '000′ hectares by region.

Year	Maize	Sorghum	Millet	Paddy	Cassava
1996	1343.3	566.7	243.2	434.5	565.5
1997	1564.1	874.2	253.6	439.3	559.4
1998	2088.3	618.4	268.1	654.5	599.4
1999	1764.4	685.5	295.8	473.9	779.3
2000	1870.5	817.9	251.8	517	1824.5
2001	1572.2	566.7	201.1	323.7	905.5
2002	2956.7	874.2	227.3	642.7	752.7
2003	2852.3	618.4	225.2	688.5	1191.9
2004	2854.2	715.8	225.8	689.6	1313.1
2005	2854.5	817.9	227.9	691.2	1345.4
2006	2570.9	715.8	338.6	633.7	993.2
2007	2600.3	817.9	346.8	557.9	779.1
2008	3980.9	1239.3	355.7	887.7	876.9
2009	2961.3	1323.4	396.5	805.6	1081.4
2010	3050.7	1239.3	452.7	1136.3	872.9
2011	3056.7	1323.4	456.5	1143.3	890.5
2012	3058.8	1148.3	457.6	1174.5	954.4
2013	3730.5	1170.8	421.2	1276.4	1034.5
2014	3729.5	1285.7	453.2	1254.7	1154.8
2015	3854.6	1389.6	467.9	1364.3	1254.3
2016	3860.5	1390.5	470.5	1375.8	1260.7
2017	3905.6	1456.8	486.3	1390.4	1286.5
2018	3950.5	1463.3	495.6	1410.6	1321.8
2019	4010.7	1480.4	498.8	1422.3	1353.4
2020	4038.5	1485.5	512.5	1430.9	1370.4

Source: Extracted from Ministry of.

the major food crops that determine food security. The results are supported by numerous studies by other scholars (Rowhani et al. 2011; 2017b; Mkonda and He 2018b), just to mention a few.

4. Discussion

The results of this empirical study indicates that soil, climate and crop factors have been insignificantly addressed in the country. In addition, although some crops are preferentially produced, the overall production for each crop is considerably low (Fig. 4). Despite of the accrued crop yields in Fig. 3, it is obvious that this increase is solely attributed by farm expansion as seen in Table 4 and not due to increase in yield per unit area. We are determining the yields in order to establish the reality that something has been wrong either in the policy framework or in its implementation (Paavola 2008).

So far examples from other countries exhibit some differences from Tanzania on how to increase yields. The developed countries seem to be more careful in increasing yields. China for instance, realized that the three factors i.e. soil, climate and crops are the major aspects to quickly deal with if the country needs to produce surplus food. On this basis, the country established intensive irrigation scheme using ground water. In so doing, various areas and more especially Chengdu Province were spotted to ensure sustainable irrigation. This is the basis at which the maximum potential photosynthetic yields is slotted at 10^{-6} Mg/g (160 Mg/ha) in most developed countries including China. While intensive irrigation was already controlled, the country further ensured soil fertilization and the breeding of crop varieties. These were practical through serious political will in agricultural investment.

In Tanzania, these factors have been merely controlled. This is evident from the report by IPCC (2014) which elucidate that Tanzania is among the thirteen countries which are most impacted and vulnerable to climate change. In addition, the statistics from FAO, further clarify that Tanzania uses 9 kg per hectare of chemical fertilizer the amount which is even less that the southern African countries i.e. 16 kg per hectare. On other hand, there has been imbalance between the actual requirements and the amount of seeds produced. This is another major reason for why the country has the maximum potential photosynthetic yields of only 3–5 Mg/ha. This is very low compared to that of the developed countries.

Literally, the preference in some crops has significantly contributed to dogmatism when comes to change of crops and/or crop varieties (Table 5). That is why in some areas farmers i.e. especially smallholder farmers have been reluctant to uproot their indigenous crops and species despite the vulnerability to climate change impacts.

Although the preference may be worthy, the impacts of global environmental change have severely affected the production in most vulnerable ecosystems (Ahmed et al., 2011; Lobell et al., 2008). Thus far, the situation necessitates the intensification of agricultural systems. In the verge of this, agricultural experts and policy makers need to do a great job to synchronize the situation. In some incidences, professionals have been pointing fingers to policy makers and implementers that they are not doing enough while the counterpart have been doing the vice versa. From this note, we learn that there has been a loose connection between and among these agricultural practitioners.

Despite the implementation of numerous plans, programs and initiative at national level, there has been high inconsistency of crop yields in various years. In some cases and areas, the observed self-sufficient ratio has been reported to exceed 100% while some areas had little on hand. This propensity eventually appeared to have the least contribution in overall. However, the major problem for this predisposition is insufficiency harness of both arable and irrigable lands. As of

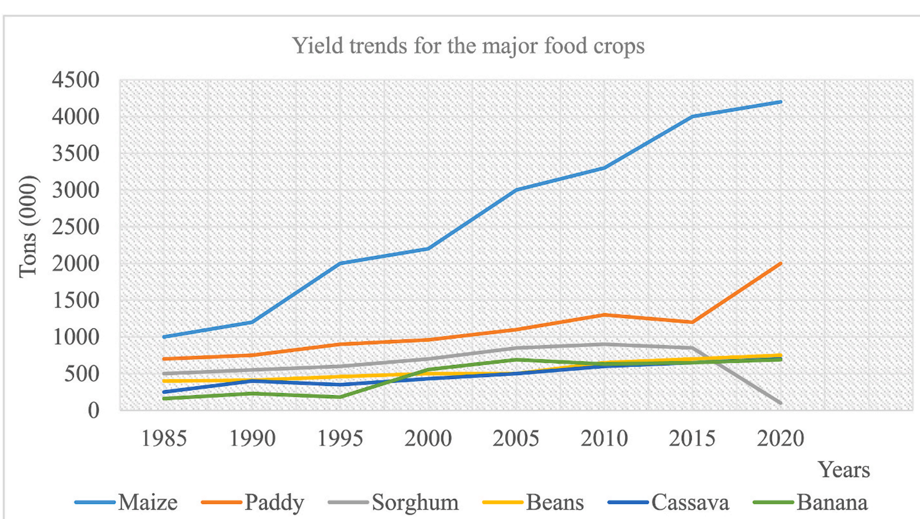

Fig. 3. Yields trend of the major food crops in Tanzania from 1985 to 2020. Source: Analyses from the data obtained from the Ministry of.

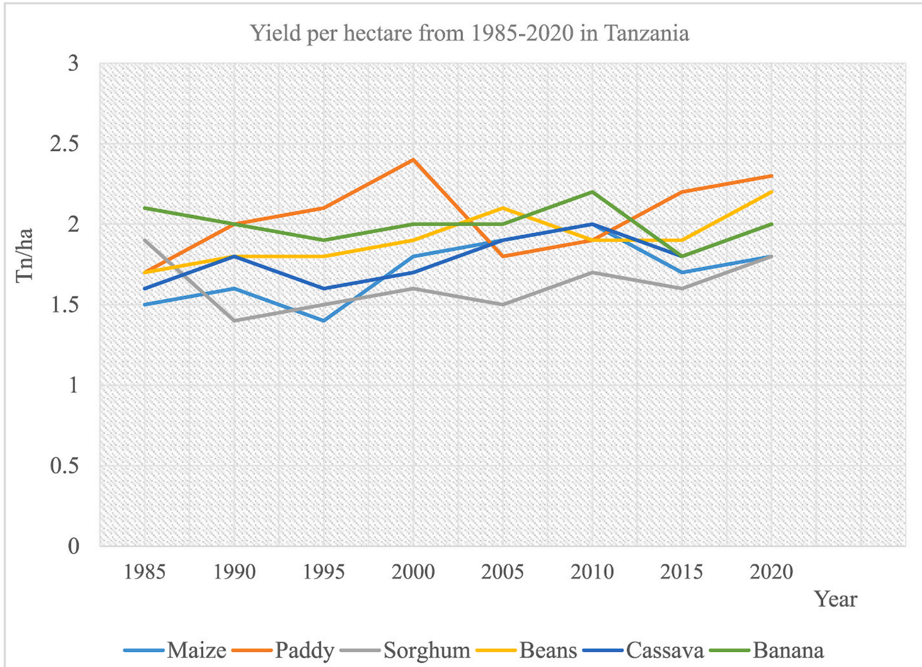

Fig. 4. Yields of the major food crops per hectare in tons in Tanzania from 1985 to 2020 **Source:** Analyses from the data obtained from the Ministry of.

Table 5
Preference level of major food crops and its magnitude of production.

Crops	Preference at national level (%)	Production per area
Maize	>70	Very high
Sorghum	<50	Very high
Millet (finger and bulrush millet)	<50	Very high
Paddy	<70	High
Wheat	>50	Low
Sweet Potatoes	>50	Medium
Irish potatoes	<50	Medium
Pulses	<50	Low
Beans	>50	High
Bananas	>50	Very high
Cassava	>50	High
Groundnuts	<50	Medium
Simsim	<20	Low
Sunflower	<50	Medium

Source: Ministry of.

recent in 2018, the Tanzanian government aims to increase the efficiency of agricultural intensification by expanding the land under agriculture and irrigation (from around 0.5 mil to 1 million hectares), however, the expected outputs are still inadequate to curb the deficit.

Almost all regions in central Tanzania are characterized by semi-arid climate and thus, more vulnerable to any increased climate stress. It is this reason which compels the agricultural planners to think big on how to get rid from this verge. The regions of Dodoma, Singida, Shinyanga, Manyara, Tabora, Simiyu, Geita and some parts of Morogoro, Iringa and Rukwa are consequently facing frequent food shortage in most years. According to population census of 2012 and its projections, these areas are the homes of about 15 million people who are always victims to any environmental stress (URT, 2013).

To improve the resilience of these people, there is a need develop small and medium irrigation schemes that can supplement water during stress and can enable at least two growing seasons in a year (Lobell et al., 2008). This will subsequently improve the livelihoods of the people especially smallholder farmers (Mkonda et al., 2018). Improvement of irrigation is recommended because most of these region have fertile (rich in nitrogen, phosphorus, carbon and potassium just to list a few). Therefore, this fertile soil will give more yields under irrigation agriculture.

The current treatment in these areas is that, the government has been insignificantly supplying fertilizers in these semi-arid areas earmarking in irrigation schemes (Mkonda and He 2018a). The discussion with the officers at the Ministry of Agriculture confirmed that, this deliberate supply of fertilizer meant to elevate yields in irrigation scheme. It is only under irrigation scheme, in arid areas, where fertilizer can work properly. In other words, shortage of irrigation scheme limits more supply of fertilizers. Further, we realized that since ammonia (NH_4) is naturally dominant in lowland (especially in water logged areas) and nitrate (NO_3) dominant upland areas, the application of chemical fertilization would deliberately consider this phenomenon. The areas with low ammonia could need to receive more of it as applied to nitrate. However, the consideration of this nutrient availability during fertilizer application was not effective.

On the other hand, the level of extension services across the country was found insufficient. This is mainly due to few human and financial resources allocated to this services. Theoretically, at least every village should have one extension officer dealing with agricultural activities. However, financial shenanigan has been a major limitation to this (World Bank 2015). Thus, most farmers, who are smallholders with least exposure to advanced methods of farming, are not updated with new methods of adapting to environmental stress. Therefore, leaving them alone or with partial instruction has left them victims to the stress.

Despite the contribution to national food security, the potentials of various hydro-ecological zones such as Kilombero, Rufiji, Ruaha, Pangani and Wami-Ruvu valleys have been insignificantly harnessed (Lalika et al., 2017; Mkonda and He 2018a). This is accompanied with high level of degradation in these areas. For example, there has been mismanagement of these areas and mostly this has been attributed by resource use conflicts. In most of these areas, the major conflicting activities are irrigation, fishing, livestock keeping, hydro-electric power and water for domestic use. These activities need to be well harmonized otherwise mismanagement may be more pronounced in the future. Therefore, there is a need build more capacity of these hydrological areas so that they can provide more benefits to the people and contribute to food security and economy of the country.

5. Conclusions

This empirical study concludes that despite the emphasis on the increase in yields of important crops to determine food security; the aspect of sustainable agriculture should be taken into account in the whole country (Tanzania). This is because increasing productivity, at all costs, sometimes leads to overexploitation of aquifers and other related environmental problems due to overfertilization. This condition is also warned by various recent FAO guidelines. Specifically, this study suggests the adoption of various agricultural approaches to intensify agriculture while conserving the environment. Considerably, there is a need to expand the land under agriculture from the current one (˜25% of the total arable land), raise the level of fertilizer inputs (i.e. from 9 kg/ha to about 50 kg/ha), and increase land under irrigation agriculture without degrading the environment. Therefore, sustainable agriculture especially under climate change scenario and soil degradation; will ensure the sustainability of the environmental health conditions for agriculture and environmental requirements for many years in future.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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