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BOTSWANA INSTITUTE FOR DEVELOPMENT POLICY ANALYSIS

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ABSTRACT

We investigate the patterns and determinants of subsistence acreage diversity in Botswana for the period 1978/79-2013/14, focusing on the role of input subsidies. Results suggest that acreage diversity declined during 1978/79 - 1987/88, due to increasing concentration on the dominant crop of sorghum. However, acreage diversity rose during 1987/88 - 2006/07, owing to falling concentration on sorghum production. Acreage diversity then fell again during 2006/07 - 2013/14 because of increasing concentration on maize, which had by then become a dominant crop. We found increased rainfall in the current year to yield a decline in acreage diversity in the current year, as farmers increased maize (a riskier crop climate-wise) acreage share, and reduced beans/pulses (a less risky crop) acreage shares. However, increased rainfall in the current year causes risk-averse farmers to reduce sorghum (a drought tolerant crop) acreage share and to increase maize, beans/pulses and groundnuts acreage shares in a subsequent year. Trend variable coefficients reveal increased acreage diversity over time, which may have been induced by extension messages and programs meant to promote crop diversity away from traditional staple cereals into non-cereal crops. The ISPAAD input subsidy program has yielded reduced acreage diversity, due to its negative impact on maize and beans/pulses acreage shares. Such unintended effects imply that ISPAAD has conflicted with the national objective of promoting agricultural diversification.

Keywords: Africa, Botswana, Agricultural input subsidies, crop diversification, subsistence economy, climate

JEL Classification: Q12, Q18

1. INTRODUCTION AND CONTEXT

Since the early 1980s, one of Botswana's development policy objectives has been to promote economic diversification into non-mining activities (Seleka, 2005). In pursuit of this policy, government has introduced economy-wide economic incentive schemes, such as the Financial Assistance Policy (FAP) and the Citizen Entrepreneurial Development Agency (CEDA). The incentive schemes have been geared at providing grants and subsidized loans to investors, to further promote enterprise development across non mining sectors, including agriculture. As further pursuit of economic diversification, government introduced the Economic Diversification Drive (EDD) initiative in 2010, which is intended to promote economic diversification across economic activities, including agriculture (Ministry of Trade and Industry, 2014).

Within the agricultural sector, public policy has also aimed to promote horizontal diversification from staple cereals and beef production into non-traditional activities such as horticulture, poultry, dairy and piggery (Seleka, 2004). As a result of such effort, there has been growth in some of these activities, particularly in the poultry industry where the country is said to be self-sufficient in broiler and egg production. To a large extent, such growth has been attributed to FAP and CEDA funding, and import restricting cross-border measures pervasive across nontraditional agricultural activities (TRANSTEC & BIDPA, 2010; Seleka, 2006).

While growth in non-traditional agriculture has been mainly propelled by economy-wide economic incentive schemes, this has not been the case for the food-grains sub-sector, which has remained largely a subsistence activity. Due to its persistently low productivity levels, the sub-sector has generally lacked competitiveness, and, hence, has been unable to attract potential investors and to undergo commercialization (Seleka & Lekobane, 2017). However, sub sector-specific programs have been launched to promote food security and commercialization in the subsistence economy. The most prominent of these programs are the Accelerated Rainfed Arable Program (ARAP) and the Integrated Support Program for Arable Agriculture Development (ISPAAD). The two programs have provided funds for expanding cultivated acreage and free and subsidized inputs (fertilizer and seeds) to farmers to promote output and productivity growth, and commercialization.

A pertinent question relates to whether ARAP and ISPAAD have also stimulated crop acreage diversity in Botswana's subsistence economy, which has traditionally been dominated by the production of staple cereals of sorghum and maize. This is an important question because one of the key agricultural policy objectives in Botswana is to diversify the food-grains sub-sector to reduce its dependence on staple cereals (sorghum and maize) and to increase the production of oilseeds (sunflower and groundnuts), and thereby commercialize the sub sector (Ministry of Agriculture, 1991).

Crop diversification can assist smallholder farmers to manage production risk by protecting them against the adverse effects of harsh climatic and ecological conditions (Di Falco & Chavas, 2009). Unlike mono-cropping production systems which can expose farmers to the adverse effects of climate variability and change (Lunduka, Ricker-Gilbert & Fisher, 2013), ex ante production decisions such as crop choice and diversification may play a pivotal role in risk management (Chibwana, Fisher & Shively, 2012; Di Falco & Chavas, 2009). To this extent, crop (or variety) diversity has historically been used by risk-averse farmers as natural or self-insurance against the adverse effects of harsh climate, since different crops do not respond in the same ways to harsh weather events (Baumgärtner & Quaas, 2003; Di Falco, Bezabih & Yesuf, 2010; Di Falco & Chavas, 2009). Crop diversification has also been viewed as a viable strategy for increasing farm-level productivity in moisture-stressed, ecologically fragile agricultural production systems (Chibwana, et al., 2012; Di Falco & Chavas, 2009; Di Falco, Chavas & Smale, 2007; Di Falco et al, 2010).

Despite the benefits of crop diversification outline above, more recently, there has been a general trend in Sub-Saharan Africa (SSA) to move towards planting a few crops so as to meet caloric needs and increase income (Chibwana, et al., 2012). For example, sole-cropped, unfertilized maize has become the prominent cropping system throughout Southern Africa, in turn leading to yield stagnation (Snapp, Rohrbach, Simtowe & Freeman,2002). This has caused policymakers to advocate the introduction of legumes as a strategy to improve soil fertility under cereal-based smallholder production environments.

There is widespread agreement that input subsidies can play a pivotal role in increasing agricultural productivity and reducing poverty (Chibwana, et al., 2012; Lunduka, et al., 2013). However, one of the unintended effects of input subsidies is that they may encourage farmers to concentrate on a few crops, which conflicts with the objectives of many governments and international development agencies to promote crop diversification. For example, the Malawi's Farm Input Subsidy Program was found to have led to increased concentration of land on the production of tobacco and maize, away from other crops such as groundnuts, soybean and dry beans (Chibwana, et al., 2012).

This paper examines the patterns and determinants of crop acreage diversity in Botswana's subsistence economy for the period 1978/79-2013/14. Primarily, the paper is geared at determining whether Botswana's input subsidy programs (ARAP and ISPAAD) have played a role towards promoting crop diversification, or whether they have instead promoted crop concentration. These programs are unique in that, in addition to providing seasonal inputs (fertilizers and improved seeds), they have also provided ploughing/planting grants, further yielding expanded land cultivation. Therefore, it is possible that they could have yielded different impacts than what has been generally observed elsewhere on the African continent. The paper adds to the scarce literature on the link between input subsidies and crop diversification in the developing world.

The rest of the paper is organized as follows. We first provide a brief background on public policy on economic diversification in general and agricultural diversification in particular, together with the emerging research issue. We then present the empirical strategy for examining the patterns and determinants of crop acreage diversity in Botswana's subsistence economy. Next, we discuss the data used to estimate the respective models. This is followed by a discussion of the empirical results. Lastly, we provide concluding remarks and draw policy implications.

2. BACKGROUND AND POLICY CONTEXT

Botswana has been pursuing economic diversification as a development strategy since the early 1980s (Seleka, 2005). The importance of economic diversification was highlighted through, inter alia, the adoption of "Sustainable Economic Diversification" as a theme for the country's National Development Plan (NDP) 8, which was implemented during the period 1997/98-2002/03 (Ministry of Finance and Development Planning,1997). Economic diversification was further given prominence in the country's NDP 9 (2003/04 - 2008/09), which adopted the development theme "sustainable and diversified development through competitiveness in global markets" (Ministry of Finance and Development Planning, 2003).

The adoption of the economic diversification policy was meant to accelerate growth in the non-mining sectors and to reduce the risks associated with heavy reliance on minerals, which are an exhaustible resource. Various economy-wide and sector-specific economic incentive schemes have been launched to facilitate the implementation of the economic diversification strategy. One of the first economy-wide programs was the Financial Assistance Policy (FAP), which was in place during the period 1982-2000, as a grant/subsidy scheme geared at promoting enterprise development outside of mining and beef production (Molokomme, 1992).

During its lifespan, FAP provided support for the development of, among others, nontraditional agricultural activities, notably, horticulture, dairy, poultry (broiler and egg production)and piggery (Rebaagetse, 1999).[1] However, most of the FAP-funded agricultural enterprises were for sheep and goat production, which is a traditional agricultural activity. This is perhaps because sheep and goat farming was seen as less risky than nontraditional enterprises by potential investors, due to the relative ease with which the breeding (capital) stock could be liquidated (converted into cash) (Seleka, 2004).

FAP was succeeded by the Citizen Entrepreneurial Development Agency (CEDA) in 2002, which is an economy-wide program intended to promote economic diversification through stimulating the development of citizen-owned enterprises. Rather than provide grants/subsidies to all eligible investors, as was the case for FAP, CEDA (currently in operation) provides loans to citizen investors at highly subsidized interest rates. Within the agricultural sector, CEDA funding has also gone into promoting enterprise development in nontraditional agriculture. Thus, both FAP and CEDA have played a pivotal role towards promoting diversification into nontraditional agriculture, particularly in the poultry industry where domestic production has skyrocketed to levels where the country is almost self-sufficient in broiler and egg production (Seleka, 2004; TRANSTEC and BIDPA, 2010).

While economy-wide programs have been used to stimulate agricultural diversification, such programs were not utilized by farmers in the food-grains sub-sector. The primary reason may be that the food-grains industry in Botswana is highly risky and uncompetitive, owing to low and erratic rainfall and the high prevalence of drought, which have resulted in low and volatile crop yields (Seleka & Lekobane, 2017). As such, potential investors would not be readily incentivized to invest in the sub-sector, which has consequently remained a subsistence activity. However, government has designed sub-sector-specific interventions, geared at promoting food security and commercialization.

Since 1991, Botswana's agricultural policy has been geared at improving food security at household and national levels; diversifying agricultural production base to create income generating opportunities within the sector; increasing agricultural output and productivity; increasing employment opportunities; providing a secure and productive environment for those engaged in the sector; and conserving scarce agricultural and land resources for future generations (Ministry of Agriculture, 1991). These policy objectives were similar to those that existed prior to 1991, except that, in 1991, the food security strategy was introduced to replace the food self-sufficiency objective, which was said to be associated with huge economic and social costs, due to resource misallocation. Thus, agricultural diversification has been one of the key agricultural development strategies over a considerable period of time.

The agricultural diversification strategy was adopted to promote horizontal (lateral) diversification into nontraditional agriculture and vertical diversification through value addition activities (agro-processing). While diversification has been slow, some progress has been made, particularly with respect to horizontal diversification into nontraditional agricultural activities (Seleka, 2004; TRANSTEC and BIDPA, 2010). In the food-grains sub sector, public policy has aimed to promote horizontal diversification away from the production of staple cereals into oilseeds, such as sunflower and groundnuts (Ministry of Agriculture, 1991). The initial intention, which never materialized, was to develop a vegetable oil processing plant, which would serve as a pull factor and promote an expansion in oilseed production. Moreover, research agenda on food-grains was to focus on developing high yielding varieties of oil crops. It was expected that such interventions would promote commercialization in the subsistence economy, and would lead to increased household incomes and rural employment creation. However, most of the originally intended interventions were never implemented, and as such the sub-sector has largely remained a subsistence activity.

Most of the key support programs in the food-grains sub-sector have delivered input subsidies to subsistence farmers. Notable amongst such input subsidy schemes are: (1) the Accelerated Rainfed Arable Program (ARAP), and (2) the Integrated Support Program for Arable Agriculture Development (ISPAAD). ARAP, a universal input subsidy program, was in place for five years from the 1985/86 to the 1989/90 cropping season (Seleka, 1999). The program provided inputs and other forms of financial assistance to arable farmers, to further stimulate increased food-grain production and create rural employment. It had six packages when it was launched in the 1985/86 cropping season: destumping, draught power, input procurement, fencing and water development.

The destumping package provided grants to farmers for destumping a maximum of 10 hectares (ha) of their fields. However, the acreage limit was later reduced to seven hectares in the 1989/90 cropping season. The draught power component provided grants for ploughing, row planting and weeding. Each farmer was initially eligible for grants to cultivate up to a maximum of 10 hectares, which was reduced to seven hectares in 1989 (Ministry of Agriculture, 1989). Free seeds and fertilizer were provided under the input procurement package. Seeds provided to farmers were enough for planting up to 10 hectares (reduced to 7 hectares in 1989) while the fertilizer was enough for only 3 hectares (increased to seven hectares in 1989). The fencing package allowed farmers to erect perimeter fences around their fields to protect their crops from livestock. Farmers were assisted to fence-off up to six hectares of their fields. The water development component was intended to provide drinking water for human and draught animal consumption at the lands.

The main aim of ARAP was to demonstrate the benefits of improved seeds, fertilizers and weeding on crop productivity, and to further promote sustainable technology adoption in the food-grains sub-sector (Kwelagobe, 1985). However, as noted by Seleka (1999), farmers reduced arable activities after ARAP was discontinued, implying that program benefits were unsustainable.

Consistent with the initial plan, ARAP was terminated after the 1989/90 cropping season, following the completion of the 5-year implementation period. However, its packages were reintroduced, now under a drought relief program, during the cropping seasons from 1992/93 to 1995/96, after which the program was ultimately terminated (after four years of operation). An analysis of the program revealed that ARAP did lead to increased cereal cultivated area, output and yields, but such benefits could not be sustained beyond the lifespan of the program (Seleka, 1999).

ARAP-type packages were further reintroduced from the 2008/09 cropping season under the ISPAAD program, which is currently still in place. ISPAAD, also a universal input subsidy program, is aimed at increasing grain production, promoting food security at national and household levels, commercializing agriculture through mechanization, facilitating access to farm inputs and credit and improving extension outreach (Ministry of Agriculture, und). As was the case with ARAP, ISPAAD provides, among others, free seeds, fertilizers and ploughing subsidies to farmers, subject to acreage limits. From 2008/09 to 2012/13, the program provided a land cultivation subsidy to cover up to 16ha. The first 5ha were eligible for a full subsidy of P400/ha while the remaining 11ha were eligible for a 50% subsidy. If the farmer practiced minimum tillage, s(he) was eligible to receive P350/ha. Those farmers who had adopted row planting were eligible to receive an additional P150/ha. Moreover, farmers who harrowed their plots were also eligible for an additional P150/ha. Fertilizer subsidies were applied for up to a total of 16ha. The first 5ha were eligible for a 100% subsidy while the remaining 11ha were eligible for a 50% subsidy. Only those farmers who had adopted row planting were eligible for free and subsidized fertilizer.

Some modifications to program packages were made in the 2013/2014 cropping season (Ministry of Agriculture, 2013). Subsistence farmers would now receive a full subsidy for hybrid seeds to cover up to 5ha and for open-pollinated varieties to cover the remaining eligible 11ha. However, those farmers opting to use only open-pollinated seeds would receive a full subsidy for all the eligible 16ha. Subsistence farmers would continue to receive free fertilizer to cover up to 5ha. In addition, they would be eligible to receive herbicides to cover up to 5ha. They would now be eligible for a full subsidy to plough, row plant or harrow up to a maximum of 5ha. The subsidy for ploughing and row planting was set at P800/ha, while those for minimum tillage and harrowing were set at P500/ha and P360/ha, respectively. The program would also cover emerging farmers cultivating up to 150ha and commercial farmers (cultivating more than 150ha). Packages for emerging and commercial farmers are not discussed here, and they are outlined in Ministry of Agriculture (2013).

Since its inception, ISPAAD has had a highly ambitious component for perimeter fencing. Instead of fencing-off individual farmers' fields as was the case for ARAP, eligible farmers would now form contiguous clusters of sizes ranging from 150ha to 350ha. Each group forming a cluster should have a constitution and a Land Board certificate pertaining to the entire cluster, to allow for cluster fencing. However, farmers within a cluster were to retain ownership of their individual plots. A further requirement is that all land within the cluster should have been destumped or if not, it should be destumped within one year from fencing-off the cluster.

While ARAP and ISPAAD may have enhanced growth in output and food security at a household level, it is important to ascertain whether these programs have also promoted acreage diversity, which is one of the agricultural policy objectives in Botswana. This is important for policymakers to understand because if the programs have instead improved crop concentration, the design of the ISPAAD program, which is currently being implemented, may need to be revisited. Further, in such a case, policymakers may need to decide on which of the two conflicting objectives, increased food security or increase crop diversity, should take precedence. This paper, therefore tackles this issue by estimating the impact of ARAP and ISPAAD on subsistence acreage shares and acreage diversity in Botswana.

3. METHODOLOGY

3.1 MEASURING CROP ACREAGE DIVERSITY

Existing crop production data classify crops grown in Botswana's subsistence economy into seven categories of sorghum, maize, millet, beans/pulses, groundnuts, sunflower and other crops. The category of other crops is an aggregate of minor crops such as melons, sweet-read and pumpkins.[2] Reallocation of acreage across these crops would change the pattern of crop diversity. To examine such patterns of crop diversity, this paper adopts four indices commonly used in applied economics to measure diversity; Inverse Herfindal, Simpson, Shannon and Pielou. Adopting four indices allows us to determine whether the results are consistent, and further adds confidence to the findings.

The Inverse of the Herfindahl index is derived from the general diversification index I^G:

$$I_{irt}^{G} = \left(\sum_{i=1}^{N} S_{irt}^{\mu}\right)^{\frac{1}{1-\mu}} \quad (1)$$

where S_{irt} is the share of planted acreage allocated to crop category i, in region r and year t, N is the number of crop categories, and μ is a parameter taking positive values other than 1 ($\mu \geq 0, \mu \neq 1$) (Tauer & Seleka, 1993). When $\mu=2$, the index becomes the inverse of the Herfindahl index, commonly used in economics to measure market and industry concentration. For the limit as μ approaches one, the index becomes the entropy index. The Simpson index I^M may be expressed as:

$$I_{irt}^{M} = 1 - \sum_{i=1}^{N} S_{irt}^{2} \quad (2)$$

where $0 \leq I^M \leq 1$ (Aneani, Anchirinah, Owusu-Ansah & Asamoah, 2011; Ibrahim, Rahman, Envulus & Oyewole, 2009; Joshi, Gulati, Birthal & Tewari, 2004). When there is only one crop, $I^M=0$ since there is complete specialization. As the extent of diversification increases, I^M increases and approaches unity for higher levels of diversity. The Shannon index I^D, which measures both richness and relative abundance, may be expressed as:

$$I_{irt}^{D} = -\sum_{i=1}^{N} S_{irt} \, lnS_{irt} \quad (3)$$

where $I^D \geq 0$, ln is the natural logarithm (Benin, Smale & Pender, 2004; Bezabih, 2008; Smale, Meng, Brennan & Hu, 2003). Finally, the Pielou index I^P, which is basically the Shannon index corrected by the logarithm of the number of crop categories, may be stated as:

$$I_{irt}^{P} = \left(-\sum_{i=1}^{N} S_{irt} \, lnS_{irt}\right) / lnN_{rt} \quad (4)$$

where $I^p \geq 0$ and N is the number of distinct crop categories (Smale, Bellon & Gómez, 2001).

3.2 ECONOMETRIC ESTIMATION

We specify two models to examine the impact of input subsidy programs on crop diversification in Botswana's subsistence economy. The first set of equations is intended to measure the impact of ARAP and ISPAAD on crop acreage shares, and may be used to make inferences on the patterns of crop acreage diversity. The equation for explaining the share of acreage allocated to crop i is specified as:

$$\frac{H_{irt}}{H_{Trt}} = \alpha + \sum_{j=1}^{n} \beta_j X_{jrt} + \sum_{k=1}^{2} \delta_k D_{krt} + \varepsilon_{rt} \tag{5}$$

where H_{irt} represents acreage (in hectares) allocated to crop i in region r and year t, H_T represents total acreage devoted to subsistence crop production, X_j is the jth explanatory variable, D_k is the dummy variable for policy k (for measuring the impact of public programs on acreage shares), α, β_j and δ_k are parameters to be estimated and ε is the error term. The coefficients β_j are the marginal effects of the n explanatory variables X_j on crop shares. Similarly, coefficients δ_k measure the impacts of the *two* policy regimes (represented by dummy variables) on crop diversity. The second set of equations is specified as:

$$I_{rt} = \omega + \sum_{j=1}^{n} \phi_j X_{jrt} + \sum_{k=1}^{2} \gamma_k D_{krt} + u_{rt} \tag{6}$$

where I is the diversification index, ω, ϕ_j and γ_k are parameters to be estimated, u is the error term, and other variables are as previously defined.

The independent variables were constructed as follows. The variables represented by X_j are rainfall for the months of October to February (the planting season), lagged rainfall for the months of October to April (the growing season) and the trend variable (T).[3] We expect rainfall to influence farmers' land allocation decisions since Botswana is characterized by rainfall uncertainty and production risk. The variable D represents two policy dummies meant to capture the impacts of ARAP and ISPAAD on crop acreage shares and diversity. The ARAP dummy takes values of one for periods when the program was in place and zero otherwise ($D_1=1$ for 1985-86 to 1989-90 and 1992-93 to 1995-96, and $D_1=0$ otherwise). Similarly, the ISPAAD dummy takes values of one for periods when ISPAAD was in place and zero otherwise ($D_2=1$ for 2008-09 to 2013/14, and $D_2=0$ otherwise). We expect input subsidies to influence farmers' land allocation decisions because they have promoted an expansion in land cultivation.

4. DATA SOURCES AND ESTIMATION

This study utilizes unbalanced panel data for six agricultural regions in Botswana (Central, Francistown, Gaborone, Maun, Southern and Western), covering the period 1978/79- 2013/14. The choice of this period was based on data availability. Data used to compute the diversification indices and crop acreage shares were sourced from various annual and census reports published by Statistics Botswana, formerly Central Statistics Office (Central Statistics Office, various; Statistics Botswana, various).

Rainfall data were obtained in spreadsheet format from the Department of Meteorological Services in Botswana. Annual rainfall estimates for agricultural regions were computed as simple averages of rainfall estimates for major stations in the respective regions. For the Central Agricultural Region, rainfall stations included Machaneng, Mahalapye, Serowe, Bobonong, Letlhakane and Selebi-Phikwe. Those for the Francistown Agricultural Region were Francistown, Tutume, Nata and Tonota. The stations used to estimate rainfall for the Gaborone Agricultural Region included Ramotswa, Gaborone, Molepolole, Letlhakeng and Mochudi, while those for the Maun Agricultural Region covered Maun, Shakawe, Gumare and Kasane. For the Southern Agricultural Region, rainfall stations included Goodhope, Lobatse, Ramatlabama and Kanye. Finally, the rainfall stations for the Western Agricultural Region were Kang, Tshane, Gantsi and Tsabong. For each cropping season, which covers parts of two consecutive years, annual rainfall for the current year was computed by summing up rainfall estimates for the months of October-February (the panting period). This is because planting activities depend on actual rainfall realized during the planting season. However, lagged rainfall estimates were based on the entire growing season (October-April) as future decisions should be dependent on rainfall (and harvest) realized during the entire cropping season.

Table 1 provides the descriptive statistics for the variables used in this study. As evident, with mean acreage shares of 36% and 40%, respectively, the cereal crops of sorghum and maize are the most dominant crops grown in Botswana's subsistence economy. With a mean acreage share of only 7%, millet, the third cereal crop, has played a less significant role in the subsistence economy. Together, the three cereal crops have recorded a mean acreage share of 83%, implying that Botswana's subsistence economy is cereal based. The shares of cereals in total planted acreage have been in the range of 56-97%, reinforcing the conclusion that Botswana's subsistence economy is cereal based. Generally, therefore, non-cereal crops form a less significant part of the smallholder production system in Botswana, with beans/pulses occupying 2-42% of cultivated acreage, oil crops (sunflower and groundnuts) accounting for only 0-24% of total crop acreage, and other crops (melon, pumpkins, sweet read and fodder) registering acreage shares of 0-19%. Similarly, mean acreage shares for beans/pulses, oil crops and other crops were estimated at only 13%, 1% and 2%, respectively.

Table 1: Variable definition and descriptive statistics

Variable	Definition	Minimum	Mean	Maximum	Median	Std. Dev.
Acreage shares:						
Sorghum	Share of sorghum acreage to total cultivated acreage	0.033	0.362	0.834	0.355	0.192
Maize	Share of maize acreage to total cultivated acreage	0.109	0.398	0.855	0.374	0.163
Millet	Share of millet acreage to total cultivated acreage	0.000	0.072	0.493	0.021	0.103
Beans/pulses	Share of bean/pulses acreage to total cultivated acreage	0.016	0.133	0.417	0.113	0.082
Groundnuts	Share of groundnuts acreage to total cultivated acreage	0.000	0.010	0.237	0.005	0.020
Sunflower	Share of sunflower acreage to total cultivated acreage	0.000	0.004	0.121	0.001	0.012
Other crops	Share of other crops (melons, pumpkins and sweetread) acreage to total cultivated acreage	0.000	0.021	0.189	0.016	0.023
Cereals	Share of cereals (sorghum, maize and millet) to total cultivated acreage	0.559	0.832	0.969	0.844	0.090
Oil Crops	Share of oil crops (sunflower and groundnuts) to total cultivated acreage	0.000	0.014	0.237	0.007	0.024
Diversification indices:						
Inverse Herfindahl	Value of the inverse of the Herfindahl index	1.355	2.700	4.592	2.667	0.655
Simpson	Value of the Simpson index	0.262	0.606	0.782	0.625	0.104
Shannon	Value of the Shannon index	0.575	1.147	1.651	1.151	0.217
Pielou	Value of the Pielou index	0.312	0.642	0.995	0.637	0.134
Independent variables:						
R_t	Millimetres of rainfall for the planting season (October- February)	84.825	329.331	716.050	314.773	116.058
R_{t-1}	Millimetres of one-year lagged rainfall for the cropping season (October-April)	151.125	409.909	838.725	395.013	139.473
R_{t-2}	Millimetres of two-year lagged rainfall for the cropping season (October-April)	151.125	415.748	838.725	400.580	138.732
D_A	ARAP and Drought Relief dummy variable (D_A=1 for 1985/86-1989/90 and 1992/93-1995/96, and D_A=0 otherwise)	0.000	0.250	1.000	0.000	0.434
D_I	ISPAAD dummy variable (D_I=1 for 2008/09-2013/14 and D_I=0 otherwise)	0.000	0.167	1.000	0.000	0.374

The descriptive statistics also suggest that rainfall in Botswana is low and highly variable across space and time (although spatial comparisons are not made in Table 1). Rainfall for the planting period, October-February, is estimated in the range of 85-716mm, with a mean of 329mm. Similarly, lagged rainfall for the entire cropping season was in the range of 151-839mm, and the means were recorded at 410mm and 416mm for R_{t-1} and R_{t-2}, respectively. The variability of rainfall is also evident from the standard deviations, which are estimated at 116mm, 139mm and 139mm for R_t, R_{t-1} and R_{t-2}, respectively.

We first estimated seven acreage share equations for sorghum, maize, millet, beans/pulses, groundnuts and sunflower. Equations for sorghum, maize and beans/pulses were estimated using the least squares method. However, due to the incidence of zero acreage shares, equations for millet, groundnut and sunflower were estimated using Tobit regression models. We then estimated models for broader crop categories of cereals (sorghum, maize and millet), oil crops (sunflower and groundnuts) and other crops, with the model for beans/pulses constituting the fourth category. The equation for cereals was estimated using least squares while those for oil crops and other crops were estimated with the Tobit model. All equations entailed fixed effects estimation, with only intercept terms allowed to vary across agricultural regions.

5. EMPIRICAL RESULTS AND DISCUSSION

5.1 STATE AND PATTERNS OF ACREAGE DIVERSITY

Figure 1 plots the diversification indices, which were computed using national, rather than regional (as specified in equations 1-4), crop acreage statistics. As evident, the patterns of acreage diversity are similar across the four indices adopted in this study. Three broad periods can be distinguished from the depicted patterns. The first period, 1978/79-1987/88, was characterized by declining crop diversity (or increasing concentration). The second period from 1987/88-2006/07 experienced increasing acreage diversity. As with the first period, the last period from 2006/07 to 2013/14 witnessed a fall in acreage diversity. A notable observation is that, across the four indices, the levels of acreage diversity in 2013/14 were lower than those for 1978/79, leading to the conclusion that, on balance, the subsistence economy failed to diversify when considering the entire review period.

To further explore the crop acreage diversification trends, Figure 2 plots the shares of acreage allocated to each crop. Evidently, staple cereals of sorghum and maize were the dominant crops throughout the review period. During the period 1978/79-1987/88, the share of acreage allocated to sorghum (which was then the dominant crop) increased, while that for maize (then the second leading staple crop) declined. The remaining crops experienced declining acreage shares. These trends imply that the period 1978/79-1987/88 was characterized by increasing concentration on the leading staple crop of sorghum. This is consistent with Figure 1 which reveals declining acreage diversification during the same period.

Figure 1: Trends in diversification indices, 198/79-2013/14

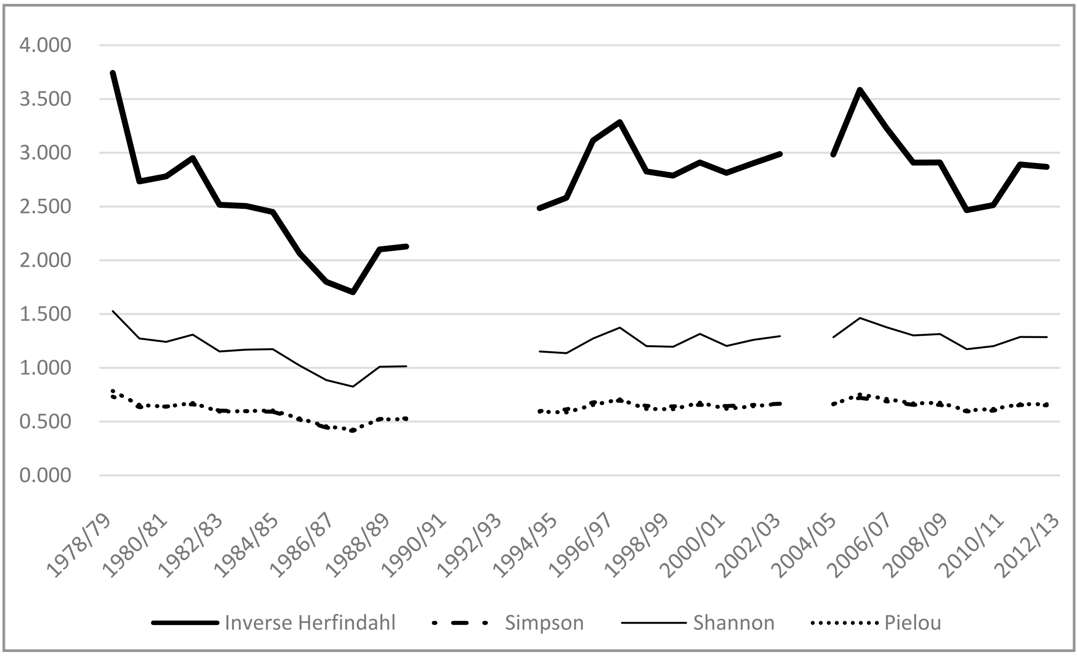
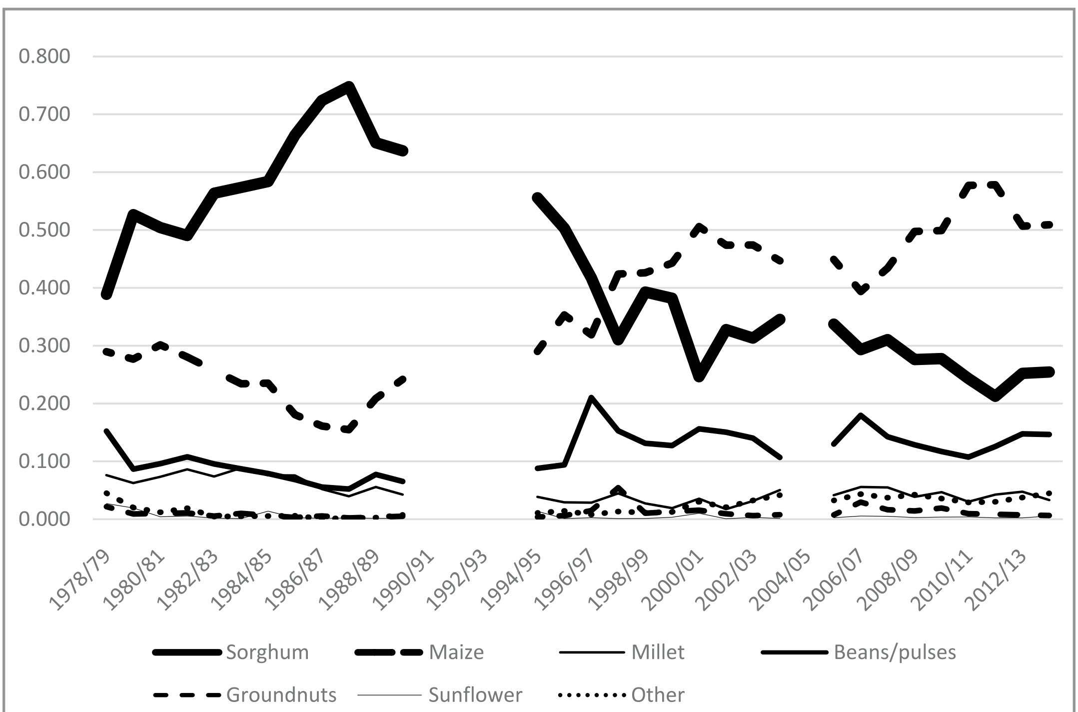


Figure 2: Crop acreage shares, 1978/79-2013/14



However, from 1987/88, a reversed scenario began to emerge, with the share of sorghum acreage declining and that for maize increasing. The share of acreage devoted to beans/pulses also began to rise until it reached its peak in 1996/97. These trends suggest reduced concentration and increased acreage diversity (Figure 1), which was mainly propelled by the reduction in acreage allocated to sorghum and increased acreage allocation to maize. However, the continued rise in the share of acreage devoted to maize meant that after 2006/07, the subsistence economy began to experience concentration on this crop, further yielding reduced acreage diversity. This occurred despite the fact that the shares of acreage devoted to "other crops" and millet had been increasing since the mid- to late 1990s, albeit from very low levels.

To empirically test the validity of the foregoing conclusions, we estimated three-period piecewise growth regressions of the form:

$$lnZ_t = \eta_0 + \eta_1 Y_t + \sum_{j=2}^{3} \eta_j (Y_t - \bar{Y}_j) D_{jt} + \nu_t \qquad (7)$$

where Z represents crop acreage share or a diversification index, Y denotes year (1979, 1980, …, 2014), $\bar{Y}_j$ is the year that begins period j ($\bar{Y}_2$ = 1988 and $\bar{Y}_3$ = 2007), D_j is a dummy variable for period j ($D_2 = 0$ for the first period and $D_2=1$ otherwise; $D_3=1$ for the first and second periods and $D_3= 0$ otherwise), v is the error term and η_0, η_1 and η_j are parameters to be estimated (Seleka, 1999). According to the specification, η_1, $\eta_1+\eta_2$ and $\eta_1+\eta_2+\eta_3$ represent annual growth rates in variable Z for period 1, period 2 and period 3, respectively.

Table 2 presents annual growth rate estimates for acreage shares and diversification indices, based on national, rather than regional, data. Consistent with the above analysis, the subsistence economy was characterized by increasing concentration (declining acreage diversity) during the period 1978/79-1987/88. The diversification indices declined by 4-5% per annum during this period. From the crop shares results, this was propelled by the increase in the share of acreage devoted to sorghum (the main crop then) and the decrease in the shares of the remaining crops. The diversification indices then rose by 2-3% per year during the period 1987/88-2006/07, mainly because of the declining share of acreage devoted to sorghum (5% per year) and increasing shares of maize (5% per year), beans/pulses (5% per year) and groundnuts (9% per year). The period 2006/07-2013/14 evidenced declining acreage diversity, with indices falling by 2-4% per annum. This was because the share of acreage devoted to sorghum declined at a lower rate (1.6% per year) than during the previous period (5% per year), while that for maize declined only slightly (0.8% per year), and those for beans/pulses and groundnuts declined substantially (4.8% and 14.8%, respectively). Millet and sunflower acreage allocations did not follow the three-period patterns. While the sunflower acreage shares declined and increased during the first two periods, respectively, the differential growth rate for the third period is statistically insignificant, implying that the growth rate estimate for the third period is not statistically different from that for the second period. Similarly, the millet acreage share declined during the first period, but the differential growth rate estimates for periods two and three are statistically insignificant.

Table 2: Piece-wise estimation of annual growth rates in acreage shares and diversification indices, 1978/79-2013/1

Crop	Estimated coefficients					Number of observations	Annual growth rates (%)		
	Constant	Y_t	$(Y_t-\bar{Y}_2)D_{2t}$	$(Y_t-\bar{Y}_3)D_{3t}$	Adj. R^2		1978/79-1987/88	1987/88-2006/07	2006/07-2013/14
Acreage shares for Individual crops:									
Sorghum	-97.682 (0.000)***	0.049 (0.000)***	-0.098 (0.000)***	0.034 (0.062)*	0.882	32	4.90	-4.95	-1.55
Maize	85.574 (0.003)***	-0.044 (0.003)***	0.096 (0.000)***	-0.061 (0.007)***	0.839	32	-4.39	5.26	-0.82
Millet	145.349 (0.014)**	-0.075 (0.012)**	0.058 (0.115)	0.048 (0.287)	0.406	32	-7.47	-1.67	3.12
Beans/pulses	116.978 (0.006)***	-0.060 (0.005)***	0.108 (0.000)***	-0.096 (0.005)***	0.556	32	-6.02	4.74	-4.82
Groundnuts	303.663 (0.003)***	-0.156 (0.002)***	0.241 (0.000)***	-0.233 (0.004)***	0.379	32	-15.56	8.58	-14.75
Sunflower	407.611 (0.008)***	-0.208 (0.007)***	0.237 (0.015)**	-0.015 (0.899)	0.171	32	-20.82	2.89	1.44
Acreage shares for crop categories:									
Cereals	-26.658 (0.001)***	0.013 (0.001)***	-0.022 (0.000)***	0.018 (0.005)***	0.607	32	1.34	-0.91	0.88
Beans/pulses	116.978 (0.006)***	-0.060 (0.005)***	0.108 (0.000)***	-0.096 (0.005)***	0.556	32	-6.02	4.74	-4.82
Oil crops	329.081 (0.001)***	-0.168 (0.001)***	0.235 (0.000)***	-0.180 (0.018)***	0.316	32	-16.81	6.65	-11.31
Other crops	547.023 (0.000)***	-0.278 (0.000)***	0.441 (0.000)***	-0.226 (0.001)***	0.820	32	-27.82	16.26	-6.38
Diversification Indices:									
Inverse Herfindahl	107.316 (0.000)***	-0.054 (0.000)***	0.081 (0.000)***	-0.068 (0.000)***	0.659	32	-5.36	2.76	-4.06
Simpson	74.017 (0.000)***	-0.038 (0.000)***	0.057 (0.000)***	-0.045 (0.000)***	0.630	32	-3.76	1.94	-2.60
Shannon	85.619 (0.000)***	-0.043 (0.000)***	0.063 (0.000)***	-0.042 (0.000)***	0.692	32	-4.31	2.00	-2.22
Pielou	84.954 (0.000)***	-0.043 (0.000)***	0.063 (0.000)***	-0.042 (0.000)***	0.692	32	-4.31	2.00	-2.22

Note. ***,** and *: statistically significant at 1%, 5% and 10%, respectively (p-values are in parentheses below parameter estimates)

5.2 ACREAGE SHARE REGRESSIONS

Rainfall

Table 3 presents Least Squares and Tobit regression estimates of acreage share equations for individual crops. As seen, rainfall at year *t* (current period) has had no statistically significant impacts on crop shares for sorghum, millet, groundnuts and sunflower. However, a 10mm rise in rainfall in year *t* (the current year) would lead to an increase of 0.09% in the share of acreage allocated to maize and a decrease of 0.05% in the share devoted to beans/pulses in the current year. Therefore, an increase in rainfall in the current year would lead to acreage substitution from beans/pulses to maize in the same year. This may be because maize is less tolerant to drier seasons than beans/pulses, and therefore a rise in rainfall would cause farmers to take increased production risk in the current year by increasing maize cultivation. Given the dominance of maize over beans/ pulses, this suggests that an increase in rainfall in year *t* may have a negative impact on acreage diversity, as it would increase acreage concentration on maize production.

The results indicate that rainfall in year *t* (the current year) would also influence farmers' acreage allocation decisions in subsequent years. This is particularly the case for the key crops of sorghum, maize and beans/pulses, which carry statistically significant coefficients for R_{t-1} and R_{t-2}. Results suggest that a 10mm increase in rainfall in year *t* would lead to a 0.2% and 0.1% reduction in the share of acreage allocated to sorghum in years *t*+1 and *t*+2, respectively. Also, a 10mm rise in rainfall in year *t* would lead to a 0.1% and 0.05% (0.06% and 0.05%) rise in the share of acreage allocated to maize (beans/pulses) in years *t*+1 and *t*+2, respectively. Additionally, a 10mm increase in rainfall in year *t* would yield a 0.02% rise in the share of acreage devoted to groundnuts in year *t*+1. However, an increase in rainfall in year *t* would have no impact on the shares of acreage devoted to millet and sunflower, and this may be because, as these crops account for smaller shares of subsistence acreage, they are considered an insignificant part of smallholder production systems in Botswana.

In sum, a rise in rainfall in the current year would induce farmers to take increased production risk by increasing land allocation to a relatively more drought-prone crop of maize and reducing land allocation to a relatively less risky crop of beans/pulses in the current year. This would yield increased concentration on maize and reduced acreage diversity since maize is more dominant than beans/pulses. Further, a rise in rainfall in the current year would cause risk-averse farmers to expect good rainfall in subsequent years, and they would respond by reducing the share of land allocated to sorghum (a drought tolerant crop and key staple) and increasing the shares of acreage devoted to maize, bean/pulses and groundnuts (riskier crops) in subsequent years. This would likely lead to increased crop acreage diversity in subsequent years due to reduced concentration on sorghum.

Table 3: Fixed effects estimation of acreage shares for individual crops, 1979/79-2013/14

Variable/Statistical	Least squares estimation			Tobit estimation		
measure	Sorghum	Maize	Beans/pulses	Millet	Groundnuts	Sunflower
Intercept	0.743	0.126	0.090	0.276	-0.019	-0.007
	(0.000)***	(0.098)*	(0.000)***	(0.000)***	(0.078)*	(0.486)
Rainfall:						
R_t	2.41E-05	9.45E-05	-5.00E-05	9.93E-06	8.05E-06	8.60E-06
	(0.577)	(0.039)**	(0.070)*	(0.798)	(0.526)	(0.420)
R_{t-1}	-2.04E-04	1.33E-04	5.91E-05	-3.00E-05	2.33E-05	1.14E-06
	(0.000)***	(0.003)***	(0.009)***	(0.347)	(0.023)**	(0.897)
R_{t-2}	-1.11E-04	4.49E-05	4.78E-05	8.18E-06	1.52E-05	-6.17E-06
	(0.003)***	(0.089)*	(0.046)**	(0.808)	(0.169)	(0.512)
Policy Dummies:						
ARAP	0.070	-0.031	-0.047	-0.021	-0.009	-0.004
	(0.001)***	(0.163)	(0.000)***	(0.052)*	(0.012)**	(0.187)
ISPAAD	0.019	-0.071	-0.044	0.011	-0.006	0.003
	(0.524)	(0.030)**	(0.000)***	(0.454)	(0.225)	(0.408)
Trend (T)	-0.013	0.007	0.002	-0.002	2.94E-0.4	-2.31E-04
	(0.000)***	(0.008)***	(0.000)***	(0.000)***	(0.092)*	(0.123)
AR(1)	0.760	0.782				
	(0.000)***	(0.000)***				
Regional Dummies:						
Southern				-0.242	-9.63E-04	0.021
				(0.000)***	(0.838)	(0.000)***
Central				-0.207	0.011	0.013
				(0.000)***	(0.025)**	(0.004)***
Gaborone				-0.213	6.83E-05	0.013
				(0.000)***	(0.989)	(0.004)***
Francistown				-0.082	0.029	0.011
				(0.000)***	(0.000)***	(0.011)**
Western				-0.278	-0.011	-0.009
				(0.000)***	(0.073)*	(0.127)
R^2	0.903	0.849	0.769			
Adj. R^2	0.895	0.837	0.755			
Durbin Watson	2.266	2.181	1.405			

Note. ***,** and *: statistically significant at 1%, 5% and 10%, respectively (p-values are in parentheses below parameter estimates)

Table 4 presents further estimates of acreage shares, based on broader crop categories: cereals, beans/pulses, oil crops and other crops. The results indicate that a 10mm increase in rainfall in the current year would lead to a 0.07% increase in the acreage share of cereals and a 0.05% reduction in the acreage share of beans/pulses in the current year. This implies concentration on cereals and reduced acreage diversity. A 10mm rise in rainfall in year t would also yield a 0.09% and 0.06% reduction in cereal acreage shares in years t+1 and t+2, respectively. However, it would further yield a 0.06% and 0.05% rise in bean/pulses acreage share in years t+1 and t+2, respectively. Further, it would yield a 0.02% increase in the share of land allocated to oil crops in year t+1. The share of acreage allocated to other crops in year t+2 is not affected by rainfall in year t. On balance, the results suggest that the rise in rainfall in year t would lead to reduced crop acreage diversity in year t and increased acreage diversity in years t+1 and t+2.

Input subsidies

From Table 3, the results indicate that input subsidy programs have impacted crop acreage allocation decisions, although there are variations across the two programs (ARAP and ISPAAD). ARAP has led to a 7% increase in the sorghum acreage share, and a 4.7%, 2.1% and 0.9% decrease in the acreage shares for beans/pulses, millet and groundnuts, respectively. However, the program has had no statistically significant impact on the acreage shares for maize and sunflower. The estimates for ISPAAD reveal that the program has led to a 7.1% and 4.4% decrease in maize and beans/pulses acreage shares (respectively), but has had no statistically significant impacts on acreage shares for sorghum, sunflower, millet and groundnuts. Therefore, its impact on overall crop acreage diversity is ambiguous, pending additional results.

Table 4 shows that cereal acreage share increased by 6.3% and 4.4% due to ARAP and ISPAAD implementation, respectively. Further, ARAP and ISPAAD respectively induced a 4.7% and 4.4% fall in the share of beans/pulses acreage. ARAP induced a 1.2% fall in the share of acreage allocated to oil crops, but had no statistically significant impact on the share of land allocated to other crops. Similarly, ISPAAD has not statistically impacted the shares of land allocated to oil crops and other crops. Therefore, the overall impacts of both input subsidy programs on acreage diversity is ambiguous, subject to discussion of further results.

We can draw two important implications from program effects. First, since ISPAAD has led to a reduction in the share of acreage devoted to maize production, the program may also have reduced production risk during harsher periods since maize does not perform well during poor rainy seasons. Second, since legumes may help rebuild nitrogen stock in soils, program induced reduction in beans/pulses acreage shares implies that both ARAP and ISPAAD may have actually contributed to accelerated depletion of soil fertility in the subsistence economy, where fertilizer adoption rates are very low, even where fertilizers are provided free of charge through input subsidy programs.

Table 4: Fixed effects estimation of acreage shares by broader crop category, 1978/79- 2013/14

Variable/Statistical measure	LS estimation		Tobit estimation	
	Cereals	Bean/pulses	Oil crops	Other crops
Intercept	0.895	0.090	-0.008	0.005
	(0.000)***	(0.000)***	(0.518)	(0.698)
Rainfall:				
R_t	7.04E-05	-5.00E-05	3.98E-06	-1.65E-05
	(0.039)***	(0.070)*	(0.793)	(0.269)
R_{t-1}	-9.05E-05	5.91E-05	2.26E-05	1.48E-05
	(0.001)***	(0.009)***	(0.065)*	(0.220)
R_{t-2}	-6.20E-05	4.78E-05	1.10E-05	8.28E-06
	(0.035)**	(0.046)**	(0.403)	(0.552)
Policy Dummies:				
ARAP	0.063	-0.047	-0.012	-0.005
	(0.000)***	(0.000)***	(0.004)***	(0.193)
ISPAAD	0.046	-0.044	-0.004	-0.002
	(0.000)***	(0.000)***	(0.430)	(0.752)
Trend (T)	-0.003	0.002	5.13E-05	0.001
	(0.000)***	(0.000)***	(0.806)	(0.000)***
Regional Dummies:				
Southern			0.011	-0.005
			(0.058)**	(0.379)
Central			0.012	0.011
			(0.044)**	(0.081)*
Gaborone			0.002	0,001
			(0.725)	(0,827)
Francistown			0.031	0.010
			(0.000)***	(0.071)*
Western			-0.015	0.003
			(0.044)**	(0.611)
R^2	0.707	0.769		
Adj. R^2	0.689	0.755		
Durbin Watson	1.562	1.405		

Notes. ***,** and *: statistically significant at 1%, 5% and 10%, respectively.
(p-values are in parentheses below parameter estimates)

Trend

As seen from the trend variable coefficients in Table 3, the shares of land allocated to maize, beans/pulses and groundnuts increased by 0.7%, 0.2% and 0.0003% per year, respectively. However, those for sorghum and millet declined by 1.3% and 0.0002% per annum, respectively. This suggests reduced concentration on the initially dominant staple crop of sorghum, and increased acreage diversity over time. From Table 4, the cereal acreage share declined by 0.3% per annum, while those for beans/pulses and other crops increased by 0.2% and 0.1% per year, respectively. However, the share of oil crops has remained stagnant over time. Since cereals have the largest share of acreage, the results imply increased acreage diversity away from cereals to non-cereal crops over time, caused by unidentified factors. Plausible sources of the observed trend are increased knowledge and information on non-cereal crops over time, due to extension messages and public programs.

5.3 ACREAGE DIVERSITY REGRESSIONS

Rainfall

Table 5 reports estimates for the four diversification indices used in the study. Across the four indices, an increase in rainfall in year t (the current year) would yield a decline in crop acreage diversity in the same year. This is consistent with earlier findings that an increase in rainfall at year t would lead to an increase in the maize acreage share and a decrease in the beans/pulses acreage share, further yielding reduced acreage diversity (or increased concentration) because maize is more dominant than bean/pulses. Further, the results are consistent with the findings that an increase in rainfall in year t would lead to a rise in the acreage share of cereals and a reduction in the acreage share of beans/pulses, further leading to increased concentration on cereals and reduced acreage diversity.

However, with the exception of the Inverse Herfindahl Index equation, the results show no evidence that rainfall at year t has had an impact on crop diversity in year t+1. The estimated coefficients in the equations for the Shannon and Pielou indices are however statistically significant if we considered a one-tailed test, rather than in the current case where we adopted a two-tail test. Consistent with earlier findings however, the Inverse Herfindahl index results reveal that high rainfall in year t would induce increased acreage diversity in year t+1. This is because, as argued earlier, an increase in rainfall in year t would yield a reduction in the share of acreage devoted to the key staple crop of sorghum in favor of maize and beans/pulses, yielding reduced concentration on sorghum and increased acreage diversity.
The results are consistent with those for Smale et al. (2003) who concluded that, in Australia, a "higher average level of precipitation is negatively associated with richness of wheat varieties" and that "a better moisture regime may mean that more farmers choose to grow fewer varieties, while a delay in the onset of the rainy season implies that fewer varieties are suitable since the growing season will be shorter" (p. 23). However, the results may appear to contradict those of Di Falco et al. (2010) who observed that, in

Table 5: Fixed effects estimation of diversification indices, 1978/79-2013/14

	Inverse Herfindahl index	Simpson index	Shannon index	Pielou index
Intercept	2.222	0.537	0.992	0.585
	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Rainfall:				
Rt	-4.74E-04	-6.42E-05	-1.42E-04	-1.57E-04
	(0.046)**	(0.099)*	(0.059)**	(0.001)***
Rt-1	3.30E-04	2.79E-05	9.11E-05	5.41E-05
	(0.088)*	(0.386)	(0.138)	(0.144)
Policy Dummies:				
ARAP	-0.130	-0.026	-0.053	-0.005
	(0.243)	(0.180)	(0.136)	(0.831)
ISPAAD	-0.423	-0.026	-0.119	-0.063
	(0.006)***	(0.007)***	(0.001)***	(0.042)**
Trend (T)	0.028	0.004	0.009	0.004
	(0.003)***	(0.017)**	(0.001)***	(0.092)*
AR(1)	0.611	0.685	0.604	0.717
	(0.000)***	(0.000)***	(0.000)***	(0.000)***
R^2	0.744	0.725	0.768	0.772
Adj. R^2	0.726	0.705	0.751	0.756
Durbin Watson	2.058	1.962	2.031	2.194

Notes. ***,** and *: statistically significant at 1%, 5% and 10%, respectively (p-values are in parentheses below parameter estimates). All equations were corrected for first order autocorrelation.

Ethiopia, high rainfall in the current year would yield an increase in the number of species grown in the current year and a decrease in the number grown in the following year. They attributed their findings to the suggestion that "when more rain is available the possible set of crops that can be grown can be expanded" and that "when farmers expect harsher environmental conditions, they use more diversity to reduce risk of loss and maintain productivity through their agro-ecosystem" (p. 1701).

However, the findings are similar in that they both indicate that an increase in rainfall in the current year would induce risk-averse farmers to take increased production risk in the current and subsequent years, while harsher climatic conditions would cause an opposite response. Our results, which are based on acreage share indices, rather than a count index adopted by Di Falco, et al. (2010), indicate that in a good year, farmers would take increased production risk by instantaneously increasing acreage allocation to a relatively more drought-prone crop of maize and reducing acreage allocation to a relatively less drought-prone crop of beans/pulses. Also, a good rainfall season in the current year would cause risk-averse farmers to take increased production risk by reducing acreage allocation to relatively more drought-resistant crops of sorghum and millet, in favor of less drought resistant crops of maize, beans/pulses and groundnuts.

Input Subsidies

Across the four equations, ARAP has had no impact on crop acreage diversity, based on the fact that, though negative, all the estimated coefficients are statistically insignificant. This may be because of its mixed impacts on acreage allocation seen earlier; it resulted in increased share of sorghum acreage, reductions in the shares of acreage devoted to bean/pulses, millet and groundnuts, and no impact on the shares of acreage allocated to maize and sunflower. However, across the diversification indices, results reveal that ISPAAD has had a negative impact on crop diversity.

Trend

All the four equations indicate that acreage diversity has increased over time; since all trend variable coefficients are positive and statistically significant. This is consistent with earlier findings that showed declining acreage shares for cereal crops and increasing acreage shares for beans/pulses and other crops over time. Given that cereals have dominated the subsistence economy, this trend suggests decreasing concentration and increasing diversification. As noted earlier, this trend could have been caused by increased dissemination of extension information advocating diversification into non-cereal crops away from cereal dominated production systems. Thus, as argued earlier, this may explain reductions in sorghum and millet acreage shares in favor of maize, beans/pulses and groundnuts.

6. CONCLUSIONS AND POLICY IMPLICATIONS

The objective of this paper was to examine the patterns and determinants of crop acreage diversity in Botswana's subsistence economy. The analysis was based on panel data covering six agricultural regions and the period 1978/79-2013/14. Results indicate that the subsistence economy witnessed declining acreage diversity during the period 1978/79-1987/88, owing mainly to the increased share of acreage devoted to the then dominant crop of sorghum and decreases in the acreage shares of the second and third most prominent crops of maize and beans/pulses (respectively). Thus, this period was characterized by increasing concentration on sorghum and declining crop acreage diversity.

However, during the period 1987/88-2006/07, the subsistence economy witnessed rising acreage diversity, mainly due to a reduction in the share of acreage devoted to sorghum production and increasing acreage shares for maize and pulses/beans. During the final period, 2006/07-2013/14, the share of acreage allocated to sorghum continued to decline while that for maize continued to rise. Since maize had overtaken sorghum to become the dominant crop, the subsistence economy now became concentrated on maize production, further yielding reduced acreage diversity.

Results further indicate that rainfall is one of the key determinants of crop acreage diversity in Botswana's subsistence economy. Increased rainfall in the current year would lead to increased maize cultivation and reduced beans/pulses cultivation in the current year, but has had no statistically significant impact on the cultivation of other crops in the current year. These results appear to suggest that an increase in rainfall would instantaneously induce farmers to increase the cultivation of a riskier crop of maize and to reduce the cultivation of a relatively less risky crop of beans/pulses. In turn, this would lead to reduced acreage diversity in the current year.

Results further suggest that rainfall in the current year has impacted acreage allocation decisions in the immediate subsequent years. Specifically, increased rainfall in the current year would yield increased cultivation of both maize and beans/pulses and reduced cultivation of sorghum in years t+1 and t+2. Thus, high rainfall in the current year would induce risk-averse farmers to increase the acreage shares of relatively less drought tolerant crops (maize and beans) and to reduce acreage share of a relatively more drought-tolerant crop (sorghum) in the following two years.

Results reveal that ARAP has led to an increase in the sorghum acreage share and a reduction in the acreage shares for beans/pulses, millet and groundnuts. However, the estimates for the diversification indices show no statistically significant impact of ARAP on acreage diversity. The ISPAAD input subsidy program has led to a reduction in the shares of acreage allocated to maize and beans/pulses and has had no statistically significant effects on acreage shares for the other crops. In turn, ISPAAD has had a negative impact on acreage diversity.

We draw three implications from these findings. First, reduced cultivation of legumes induced by ARAP and ISPAAD suggests that these programs may have yielded the depletion of soil nutrients since legumes may be used to restore nitrogen in soils. Second, the ISPAAD-induced reduction in maize acreage share implies that the program may have led to reduced exposure of subsistence producers to climate risk, since maize performs poorly during harsher climatic conditions. Finally, while ISPAAD may have induced output growth through expanding cultivated acreage, it may have worked against the achievement of the government objective of promoting acreage and broader agricultural diversification. Policymakers may therefore need to look into this, although the argument could be that, given the design of the ISPAAD program, the objective to achieve household food security is more important than that of achieving crop diversification.

Overall, the results yield no evidence that the government strategy to promote diversification into oil seeds has been achieved. Instead, crop substitution has mainly been between the two dominant staples of sorghum and maize, and to a lesser extent beans/pulses. However, the trend variable estimates suggest that, over time, there has been a steady reduction in the shares of acreage allocated to sorghum and millet, in favor of maize, beans/pulses, groundnuts and other crops, and that sunflower acreage shares have remained stagnant. While the reasons for such increased diversification over time (ceteris paribus) are unknown, it could be because of extension information and knowledge dissemination to farmers, geared at promoting increased cultivation of non-cereal crops. It could have also been propelled by increased dietary diversity away from reliance on sorghum to other food crops; since subsistence farmers produce primarily to meet home consumption needs.

NOTES

1. It is however noteworthy that the failure rates of FAP supported projects were high, implying that the enterprises were unsustainable (Rebaagetse, 1999).

2. However, in recent years, fodder has been introduced in the subsistence production system in Botswana, and it is therefore included as part of "other crops".

3. Specifications that included regional producer prices of the various crops or relative crop prices were abandoned as they produced statistically insignificant or theoretically inconsistent estimates. This could be because output prices are not used in making land allocation decisions since the majority of subsistence farmers do not participate in the output market (Seleka and Lekobane, 2017). Moreover, fertilizer prices were not included in the specifications because of the low adoption rates by subsistence farmers (such prices were also unavailable).

REFERENCES

Aneani, F., Anchirinah, V. M., Owusu-Ansah, F. & Asamoah. M. (2011). An analysis of the extent and determinants of crop diversification by cocoa (*Theobroma cacao*) farmers in Ghana. *African Journal of Agricultural Research, 6(18), 4277-4287*.

Benin, S., Smale, M., Pender, J., Gebremedhin, B., & Ehui, S. (2004). The economic determinants of cereal crop diversity on farms in the Ethiopian highlands. *Agricultural Economics 31(2-3), 197-208*.

Bezabih, M. (2008). Agrobiodiversity conservation under an imperfect seed system: the role of community seed banking schemes. *Agricultural Economics, 38(1), 77-87*.

Baumgärtner, S. & Quaas, M. F. (2010). Managing increasing environmental risks through agrobiodiversity and agrienvironmental policies. *Agricultural Economics*, 41(5), 483-496.

Central Statistics Office (various). Annual Agricultural Survey Reports. Gaborone, Botswana: Statistics Botswana.

Chibwana, C., Fisher, M., & Shively, G. (2012). Cropland allocation effects of agricultural input subsidies in Malawi. *World Development, 40(1), 124-133*.

Di Falco, S., Bezabih, M. & Yesuf M. (2010). Seeds for livelihood: crop biodiversity and food production in Ethiopia. *Ecological Economics*, 69(8): 1695-1702.

Di Falco, S. & Chavas, J.P. (2009). On crop biodiversity, risk response, and food security in the highlands of Ethiopia. *American Journal of Agricultural Economics, 91(3), 599-611*.

Di Falco, S., Chavas, J. P. & Smale, M. (2007). Farmer management of production risk on degraded lands: the role of wheat variety diversity in the Tigray region, Ethiopia. *Agricultural Economics, 36(2), 147-156*.

Ibrahim, H., Rahman, S. A., Envulus, E. E. & Oyewole, S. O. (2009). Income and crop diversification among farming households in a rural area of north central Nigeria. *Journal of Tropical, Food, Environment and Extension, 8(2), 84-89*.

Joshi, P. K., Gulati, A., Birthal, P. S. & Tewari, L. (2004). Agriculture diversity in South Asia: patterns, determinants and policy implications. *Economic and Political Weekly, 39(24), 2457-2467*.

Kwelagobe, D. K., Hon. (1985). ARAP: Accelerated rainfed arable programme. Address to Parliament. Gaborone, Botswana: Botswana Parliament.

Lunduka, R., Ricker-Gilbert, J. & Fisher, M. (2013). What are the farm-level impacts of Malawi's farm input subsidy program? A critical review. *Agricultural Economics*, 44 (6), 563-579.

Ministry of Agriculture. (1989). Accelerated rainfed arable programme (ARAP) guidelines 1989-90. Gaborone, Botswana: Ministry of Agriculture.

Ministry of Agriculture, (1991). Botswana's agricultural policy: Critical sectoral issues and future strategy for development. Gaborone, Botswana: Ministry of Agriculture.

Ministry of Agriculture. (2013). Revised guidelines for integrated support programme for arable agriculture development (ISPAAD). Gaborone, Botswana: Ministry of Agriculture.

Ministry of Agriculture. (undated). Guidelines for integrated support programme for arable agriculture development (ISPAAD). Gaborone, Botswana: Ministry of Agriculture.

Ministry of Finance and Development Planning (MFDP). (1997). National Development Plan 8: 1997/8 – 2002/03. Gaborone, Botswana: Government Printer.

Ministry of Finance and Development Planning (MFDP). (2003). National Development Plan 9: 2003/04 – March 2016. Gaborone, Botswana: Ministry of Finance and Development Planning.

Ministry of Trade and Industry. (2014). Overview and Progress Update of the Economic Diversification Drive (EDD). Unpublished Report. Gaborone, Botswana: Ministry of Trade and Industry.

Molokomme, I. M. (1992). Report on FAP service sector study. Gaborone, Botswana: Ministry of Finance and Development Planning.

Rebaagetse, M. J. (1999). An overview of the performance of the agricultural projects funded through the financial assistance policy (FAP) for the period 1982-1998. Gaborone, Botswana: Ministry of Agriculture.

Seleka, T. B. (1991). The performance of Botswana's traditional arable agriculture: growth rates and the impact of the accelerated rainfed arable program (ARAP). *Agricultural Economic, 20(2), 121-133*.

Seleka T. B. (2004). Diversification in Botswana's agricultural sector: Issues, prospects and challenges. BIDPA Publication Series. Gaborone, Botswana: Botswana Institute for Development Policy Analysis.

Seleka T. B. (2005). Challenges for agricultural diversification in Botswana under the proposed SADC-EU economic partnership agreement. BIDPA Working Paper 27. Gaborone, Botswana: Botswana Institute for Development Policy Analysis.

Seleka T. B. & Lekobane K. R. (2017). Public transfer and participation decisions in Botswana's subsistence economy, *Review of Development Economics, 21(4), 1380-1400*.

Smale, M., Bellon, M. R. & Gómez, J. A. A. (2001). Maize diversity, variety attributes, and farmers' choices in Southeastern Mexico. *Economic Development and Cultural Change, 50(1), 201-225*.

Smale, M., Meng, E., Brennan, J. P. & Hu, R. (2003). Determinants of spatial diversity in modern wheat: examples from Australia and China. *Agricultural Economics*, 28(1), 13-26.

Snapp., S. S., Rohrbach, D. D., Simtowe, F. & Freeman, H. A. (2002). Sustainable soil management options for Malawi: can smallholder farmers grow more legumes? *Agriculture, Ecosystems and Environment, 91 (1-3), 159-174*.

Statistics Botswana (various). Annual Agricultural Survey Reports. Gaborone, Botswana: Statistics Botswana.

Tauer, L. W. & Seleka, T. B. (June, 1993). Agricultural diversity and cash receipt variability for individual states, Department of Agricultural Economics, A. E. Res. 93-6. Cornell University Agricultural Experiment Station, College of Agriculture and Life Sciences, Cornell University, Ithaca New York.

Transtec & Botswana Institute for Development Policy Analysis. (2010). Agricultural Sector Review. Unpublished Consultancy Report. Gaborone: Botswana Institute for Development Policy Analysis.

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