The performance of Botswana's traditional arable agriculture: growth rates and the impact of the accelerated rainfed arable programme (ARAP)

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Abstract

This study assesses the performance of Botswana's traditional arable agriculture for the 1968–90 period. Growth rate and arable sub-sector production models are specified and estimated to determine how the sub-sector performed over time, and to capture the impact of the Accelerated Rainfed Arable Programme (ARAP). Growth rate model results indicate that cultivated area increased by about 2.2% per year during the 1968–90 period. However, crop output remained unchanged and yields declined by about 6.1% per year during the review period. Sub-sectoral model results reveal that cultivated area, output and yields rose by about 27%, 120% and 74% (respectively) due to the implementation of ARAP. Therefore, ARAP was effective in improving rural household food security and welfare. However, it is further argued that the program was unsustainable since it involved phenomenal government outlays and has led to an unprecedented input substitution from animal traction to tractor traction, which seems to be unjustified given the current economic fundamentals of the country's traditional arable farming. Moreover, the results reveal loss of productivity in the sub-sector over time. Therefore, the challenge facing policy makers is to devise new ways of reversing the current trend. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

When Botswana became independent in 1966, its agricultural sector contributed about 40% to Gross Domestic Product (GDP) and by 1991 until present, this figure had fallen to about 5% (Ministry of Agriculture, 1991, 1996). This decline was largely attributable to the rapid increase in the contribution of minerals, particularly diamonds, to the country's GDP. However, agri-

culture remains a significant source of food, income and employment for the majority of rural households.

While the decline in the relative contribution of agriculture to Botswana's economy is largely attributable to the discovery of minerals, other sources of this trend originate from within the sector itself. The arable sub-sector in particular has been characterized by low productivity levels, implying low returns to labor and capital investment (Ministry of Agriculture, 1996). This poor performance has been largely attributable to low and variable rainfall and the occurrence of successive droughts. Sub-sectoral factors such as poor

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soil fertility, low adoption of improved technologies, poor farm management, inadequate farm inputs, inadequate draft power at critical times, and insufficient knowledge and training of both extension agents and farmers have also been advanced as plausible sources of low productivity levels (Seleka and Mmofswa, 1996). The poor performance in the arable sub-sector has contributed to the country's dependance on imports to secure basic cereals.

Governmental support to farmers has been substantial in an effort to increase arable production and productivity at the farm level. Various policies have been formulated and several programs implemented as an attempt to boost arable sub-sector productivity. Such programs have been accompanied by huge government outlays. Since the early to mid 1980s, two programs have dominated the arable sub-sector: the Arable Lands Development Program (ALDEP); and the Accelerated Rainfed Arable Programme (ARAP) and its variant, Drought Relief to Arable Farmers. Despite substantial government support, low and declining productivity levels continue to characterize the arable sub-sector.

This paper seeks to provide an overview of the performance of Botswana's traditional arable sub-sector and to examine the impact of ARAP on cereal cultivated area, output and yield. The traditional arable agriculture contributes significantly to Botswana's arable agriculture. Using data for the 1979–90 period and 1993, Seleka and Mmofswa (1996) ascertained that on average, the traditional arable sub-sector occupied about 90% of the country's cultivated area, and contributed about 69% of sub-sectoral output. Moreover, about 70% of the country's population derives a livelihood from traditional arable farming. The empirical work of this study utilizes cereal production statistics. The data utilized in this study indicates that cereals (Sorghum, maize and millet) are important because they occupied about 93% of the traditional sub-sector's cultivated area during the 1968–90 period. Moreover, about 94% of the traditional sub-sector's output, in terms of weight, came from cereal production.

This paper contributes in two ways. Primarily, the paper adds to the current understanding on how ARAP has affected smallholder arable farmers. Secondly, the paper constructs an econometric model that identifies the factors that have influenced the performance of the

country's traditional arable agriculture over time. The paper begins by presenting a brief historical background on Botswana's agricultural policy in general and on ARAP in particular. Next, empirical models for calculating growth rates and crop production models for determining the impact of ARAP are presented. The paper then discusses data and empirical estimation of models. A discussion of empirical results is then presented. A discussion on non-quantified effects of ARAP is presented next, followed by the final section on future challenges.

2. Background on government policy and ARAP

Since independence in 1966, the Botswana government has intervened into agriculture with a quest for increasing production and productivity. From independence to 1991, the major agricultural policy objectives were aimed at providing adequate and secure livelihood for those involved in agriculture, increasing agricultural output, increasing food self sufficiency, conserving agricultural land resources, and meeting employment demands of a growing labour force (Ministry of Agriculture, 1991). In 1991, Botswana's policy objectives were redefined to replace the food self sufficiency strategy with the food security objective, to ensure that households had access to adequate food and to promote diversification of agricultural production into horticulture, pulses, veld products and forestry. As an attempt to achieve the above policy objectives, the government put several programs into practice. Since early to mid 1980s, two programs have dominated arable farming: ALDEP[2] and ARAP, and its variant, Drought Relief to Arable Farmers.

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[2]This study does not model the impact of ALDEP. For this reason, the background information presented in this section will only be on ARAP. ALDEP has so far operated in two phases, and it is currently in its second phase. ALDEP phase I operated during the 1981–90 period. This scheme 'provided farmers with animal draft power (donkeys, oxen and mules), animal drawn implements (ploughs, planters, cultivators, and harrows), fencing materials, water catchment tanks, scotch carts and fertilizers' (Seleka and Mmofswa, 1996; pp. 2). The second phase of ALDEP, which is currently in operation, was incepted in 1991. Similar packages are provided, but 'concentration is now on strengthening agricultural extension services; technology transfer; and training/encouraging the ALDEP phase I beneficiaries to efficiently utilize the packages they obtained' (Seleka and Mmofswa, 1996; pp. 4).

ARAP was launched during the 1985/1986 crop-ping season as a five year program for assisting dry-land farmers (Seleka and Mmofswa, 1996). At its inception, ARAP was intended to assist each eligible farmer once during its lifetime (Kwelagobe, 1985). However, the guidelines were later modified to allow farmers to benefit every year during the lifetime of the program. ARAP was initially aimed at all farmers engaged in rainfed arable agriculture and not qualify-ing for benefits through the Financial Assistance Policy (FAP)[3]. The program was introduced to provide inputs and financial resources to farmers so that they could increase food production and generate employ-ment. Therefore, ARAP was introduced to achieve the goal of food self sufficiency, increase rural incomes received directly and indirectly from arable farming, and create productive and remunerative employment in the land areas.

When it was launched, ARAP included six packages: destumping, draught power, input procurement, fen-cing, water development, and crop protection. The destumping package involved a subsidy of P50.00 per hectare, and allowed each eligible household to de stump up to ten hectares of land. The draught power package included three elements: ploughing, row plant-ing and weeding. Under this package, beneficiaries were provided P50.00, P10.00 and P5.00 per hectare for ploughing, row planting and weeding, respectively.

The input procurement package provided improved seeds and fertilizer to farmers. Each farming house-hold would be supplied up to 80 kg of seeds (enough to plant up to ten hectares), and enough fertilizer to cover up to three hectares (200 kg per hectare). ARAP was intended to demonstrate the impact of improved seeds, fertilizer application, row planting and weeding on crop yields and food production. The fencing package

provided assistance to fence up to six hectares of land per farmer, to protect crops from livestock damage. The water development package provided funds for equipping boreholes and reticulating water for human and draught power requirements at the land areas. The crop protection package involved the establishment of the crop protection unit within the Ministry of Agri-culture to deal with emergency outbreaks of quelea, pests, worms and weed encroachment.

ARAP packages were modified during the 1989–1990 cropping season (Ministry of Agriculture, 1989). The draught power assistance package was modified by reducing hectares covered from ten to seven, and increasing the subsidy from P50.00 to P70.00 per hectare. For row planting, farmers would receive P20.00 per hectare for up to seven hectares. Free seeds were provided to cover up to seven hectares per farming household. The destumping package was modified to cover up to seven hectares, and the government subsidy would now vary with the number of stumps removed. Subsidies of P50.00, P60.00 and P70.00 were provided for removing 1–20 stumps, 21–30 stumps, and over 30 stumps per hectare, respec-tively. The fencing package would now provide a maximum subsidy of P1,200.00 for purchasing mate-rials (wire, poles, etc.) and paying the fence erector. The water development package would now provide a subsidy of up to P20,000.00 to groups for equipping and reticulating water for livestock and human con-sumption.

At its closure following the 1989/90 cropping sea-son, ARAP had spent about P180 million, in nominal terms. As indicated in Table 1, this amounted to P139 million in real terms, with 1986 as a base year[4]. In real terms, the amount of subsidy per beneficiary was P777, P239, P240, and P245 during the 1985/1986, 1986/1987, 1987/1988 and 1988/1989 cropping sea-sons, respectively (see Food Studies Group, 1990). As evident from Table 1, most of the subsidy went into

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[3]The Financial Assistance Policy was launched in 1982 by the government to diversify the economy into other sectors outside mining and beef production. FAP is currently operating and its specific objectives are: to 'create sustained employment for unskilled workers'; to 'diversify the economy to lessen its dependence on large scale mining, cattle and the public sector'; to 'upgrade citizen's skills through training'; to 'promote active citizen ownership of ventures'; and to produce goods for the export market and for import substitution (Molokomme, 1992; pp. 13). FAP support is and has been extended to projects in all sectors of the economy. Examples of agricultural projects supported under FAP are horticulture, poultry (broiler and egg production), sorghum milling, small stock and piggery.

[4]While ARAP was non-operational during the 1990/91 cropping season, some disbursements amounting to P14.02 million (in real terms) were made to cover outstanding accounts. In addition to expenditure on packages, monies amounting to P35.18 million, P4.47 million, and P1.85 million (in nominal terms) were spent on wages and salaries (of staff who implemented the program), transport and other activities (respectively), during the first four financial years of implementing ARAP (Food Studies Group, 1990).

Table 1
Expenditure on ARAP Packages, 1985/86–1989/90 (million of real 1986 Pula)

Package	1985/1986	1986/1987	1987/1988	1988/1989	1989/1990[a]	1990/1991[b]	Total
Destumping	0.82	1.55	2.10	1.36	na	na	na
Ploughing/Draft power	9.6	15.85	18.83	16.35	14.9	na	75.52
Row planting	0.31	0.60	1.70	1.53	1.39	na	5.52
Weeding	0.06	0.39	0.97	2.16	na	na	na
Fencing	0.002	0.27	0.93	0.86	na	na	na
Seed provision	0.44	0.69	1.54	0.09	na	na	na
Water development	0	0	0.09	0.21	na	na	na
Total	11.81	23.95	29.59	29.53	30.24	14.02	139.14
Consumer price index (1986 = 100)	100	109.8	118.97	132.75	147.89	165.27	

Sources: Modified from Food Studies Group, 1990, MoA records, International Monetary Fund.

[a] There were some missing entries for individual packages during 1989/1990. However, total expenditure on ARAP for that cropping season had been recorded.

[b] ARAP was not operating during the 1990/1991 cropping season. However, outstanding payments were made during that season.

na: Not available

the ploughing/draft power package. An assessment of the last column of the table reveals that about 54% of the total subsidy went into this package. This implies that most of the subsidy went into expanding cultivated area. In real terms, with 1986 as a base year, the ploughing subsidy per beneficiary amounted to P810, P394, P262 and P264 during 1985/1986, 1986/1987, 1987/1988 and 1988/1989 cropping seasons, respectively (see Food Studies Group, 1990).

ARAP was terminated after the 1989/1990 cropping season. In the 1992/1993 cropping season, a variant of ARAP, Drought Relief to Arable Farmers (DRAF), was introduced to help farmers regain their production base and to improve productivity, to create employment and income generating opportunities in the rural areas, and to enable the population to improve its food security situation. DRAF was ideally a continuation of ARAP in terms of packages offered. This programme was in operation until the 1995/1996 cropping season when it was subsequently discontinued.

3. Empirical models

3.1. Growth rate model

This section presents the empirical model for estimating growth rates for cereal area planted (A), production (Q) and yield (Q/A). The purpose is to be able to assess the performance of the traditional arable sub-sector over time. A multi-period piecewise growth model was specified as

$$\ln X_t = \alpha_0 + \alpha_1 Y_t + \sum_{j=2}^{n} \alpha_j (Y_t - Y^j) D_t^j + u_t \quad (1)$$

where X is the variable of concern (A, Q and Q/A), ln is the natural logarithm, Y denotes year (1968, 1969, ... ,1990), Y^j is the year that begins period j, D^j denotes a set of dummy variables for capturing the differential (incremental) growth rates for period j ($D^2 = 0$ for years that fall within the first period and $D^2 = 1$ otherwise; $D^3 = 0$ for years falling within the first and second periods and $D^3 = 1$ otherwise; ... ; and $D^n = 0$ for years falling within the first, second, third, ... , and $n-1$th periods and $D^n = 1$ for the nth period), α_0, α_1 and α_j are parameters to be estimated, u is the random disturbance term and t denotes year.

Eq. (1) simply combines the features of a single period growth model and those of a piecewise linear regression (Gujarati, 1988), to construct a multi-period piecewise growth model. According to Eq. (1), α_1 is the annual growth rate of variable X during the first period and α_2, α_3, ... , and α_n are differential annual growth rates for subsequent periods. The annual growth rate for any period $k = (1, ... ,n)$ is calculated as

$$r_k = \sum_{j=1}^{k} \alpha_j \quad k = 1, ... ,n; \quad j = 1, ... ,n \quad (2)$$

Therefore, annual growth rates for the 1st, 2nd, 3rd,···, and nth period are calculated as $r_1 = \alpha_1$, $r_2 = \alpha_1 + \alpha_2$, $r_3 = \alpha_1 + \alpha_2 + \alpha_3,···$, and $r_n = \alpha_1 + \alpha_2 + ··· + \alpha_n$, respectively.

3.2. Arable sub-sector production model

This section constructs Botswana's cereal production model for the traditional arable sub-sector. The model is specified to be able to capture the impact of ARAP. As already mentioned, ARAP was launched in the 1985/1986 cropping season as a five year program intended to increase acreage, production and crop yields. Among other things, ARAP provided ploughing subsidies to farmers to expand cultivation area, and to increase crop output and yield. This section, therefore, constructs a model for quantifying the effects of ARAP on cereal planted area, output and yields, for the traditional arable sub-sector.

The traditional arable sub-sector cereal production model is specified as

$$\ln A_t = \alpha_0 + \alpha_1 \ln \text{ROF}_t + \alpha_2 T_t + \alpha_3 D_t + u_t \quad (3)$$

$$\ln\left(\frac{Q_t}{A_t}\right) = \beta_0 + \beta_1 \ln \text{ROA}_t + \beta_2 T_t + \beta_3 D_t + v_t \quad (4)$$

where A represents cultivated cereal area, ROF denotes average rainfall for the months of October through February (the ploughing/planting season), T is an annual trend variable, D_t is the dummy variable for capturing the effect of ARAP ($D_t = 0$ during years without ARAP and $D_t = 1$ during ARAP years), Q is cereal output, ROA is average rainfall for the months of October through April (the growing season), u and v are random disturbance terms, ln is the natural logarithm, αs, and βs are parameters to be estimated, and t denotes year.

As previously noted, there was an overlap between ARAP and ALDEP. ALDEP Phase I was in place during 1981 through 1990. During this time, ALDEP assisted farmers with animal draft power (donkeys, mules, and oxen), animal drawn implements (ploughs, cultivators and harrows), fencing materials, water catchment tanks, and scotch carts. While there was an overlap between the two programmes, the dummy variable included in the model of this study was intended to only capture the ARAP effect, which

occurred during the 1985/86 through 1989/90 cropping seasons. It is possible that there may have been some interaction effect of the programmes during the ARAP period, implying that the presence of ALDEP may have enhanced the effects of ARAP. However, since there was input substitution away from animal traction (offered through ALDEP) to tractor traction during the implementation of ARAP, one would expect such interaction effect to be minimal[5].

Expression 3 is the cereal acreage equation and expression 4 is the cereal yield equation. Ideally, the explanatory variables of Eq. (3) should include other production factors such as labour. Moreover, Eq. (4) should have included fertilizer as one of the explanatory variables. Such variables were not included because of the unavailability of data. The exclusion of fertilizer should however not present specification problems, because a large majority of traditional farmers have not adopted the fertilizer technology. Eqs. (3) and (4) should normally include the output price as one of the explanatory variables affecting supply response (see Mamingi, 1997). However, since we are modelling the traditional sub-sector, this variable was not included. Traditional farmers in Botswana cultivate for subsistence purposes, and crop sales are usually made during good years when production exceeds home storage. One would therefore expect acreage, yield and output not to respond to price changes. The output response equation was derived from Eqs. (3) and (4). This was done by replacing $\ln(Q_t/A_t)$ with $(\ln Q_t - \ln A_t)$ in Eq. (4), substituting the right-hand side of Eq. (3) into the resulting expression (in place of $\ln A_t$) and rearranging terms to yield

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[5]An attempt was made to ascertain whether or not ALDEP had an impact. The model for cultivated area was respecified as: $\ln A_t = \alpha_0 + \alpha_1 \ln \text{ROF}_t + \alpha_2 T_t + \alpha_3 D_t + \alpha_4 (T_t - \bar{T})\text{ALD}_t + u_t$, where ALD is the ALDEP dummy (ALD = 0 during non-ALDEP years and ALD = 1 during ALDEP years), and $\bar{T}$ is the value of the trend variable during the year that ALDEP was introduced (in this case $\bar{T} = 16$). The resulting ALDEP variable $(T_t - \bar{T})$ ALD$_t$ took values of zero during the 1968–1981 period and took values of 0, 1, 2, . . . , 8 during 1982, 1983, 1984, . . . , 1990, respectively. This was in light of the fact that ALDEP impact, if any, would have been progressive (increased over time). The coefficient α_4 was meant to capture the incremental change in the trend variable associated with ALDEP. This coefficient would have been positive if ALDEP had an impact on cultivated area. This model yielded fruitless results and provided no indication that ALDEP had an impact on cultivated area.

$$\ln Q_t = (\alpha_0 + \beta_0) + \alpha_1 \ln \mathrm{ROF}_t + \beta_1 \ln \mathrm{ROA}_t$$
$$+ (\alpha_2 + \beta_2)T_t + (\alpha_3 + \beta_3)D_t + (u_t + v_t) \quad (5)$$

This equation ensures that output response combines both the acreage and yield responses.

It is hypothesized that the coefficient α_1 is positive since farmers are expected to cultivate more land under dryland conditions as rainfall increases. The parameter α_2 is expected to be positive since cultivated cereal area is expected to have increased over time with the introduction of new entrants into farming, and the expansion of cultivated land by existing farmers. The coefficient α_3 is hypothesized to be positive since ARAP was intended to increase cultivated area. The parameter β_1 is expected to be positive since cereal yield is expected to increase with rainfall. The coefficient β_2 is hypothesized to be negative due to productivity decline over time. This is because the majority of traditional farmers in Botswana have not adopted improved technologies, such as fertilizer use, that would have improved or sustained land productivity over time. Therefore, productivity is expected to decline over time due to the loss of soil fertility from repetitive use of land. The parameter β_3 is expected to take a positive sign since ARAP should have led to an increase in productivity.

4. Data and empirical estimation

Annual crop production statistics covering the 1968–90 period were obtained from ARUP ATKINS International Limited (1989) and the Ministry of Agriculture (Agricultural statistics). This period was selected because crop production data were unavailable for years preceding 1968 and for the 1991–92 and 1994–95 cropping seasons. Total cereal area planted and output were computed by summing across the three cereal crops planted by traditional farmers: sorghum, maize, and millet. As previously noted, these crops occupied about 93% of total cultivated area and contributed about 94% of total output, in terms of weight, in the traditional sub-sector during the 1968–90 period.

Monthly rainfall statistics were obtained from the database for Botswana Meteorological Services (MBS). The data provided by MBS were for 94 stations located throughout the country. However, since many stations had missing observations, only ten stations with complete data were selected to represent the country. These stations include Francistown, Gaborone, Gantsi, Kanye, Kgale, Mahalapye, Maun, Palapye, Phitshane-Molopo, and Tsabong. The stations are fairly well distributed throughout the country, and should be fairly representative of the various agro-ecological regions of Botswana. Moreover, the eastern part of the country where arable agriculture is mainly concentrated is represented by six stations (Francistown, Gaborone, Kanye, Kgale, Mahalapye, and Palapye) and the other areas are represented by the remaining four stations (Gantsi, Maun, Phitshane-Molopo, and Tsabong). Monthly rainfall data for the country was calculated as a simple average of these ten stations[6].

Rainfall estimates for any given period (October through February and October through April) were computed as the sum of monthly rainfall data for the months in question[7].

Ordinary Least Squares (OLS) was used to estimate the growth model Eq. (1). In estimating growth rates, three periods were distinguished; 1968–1974, 1974–1985 and 1985–1990. These periods were based on trends in cereal cultivated area, output and yields, which were similar. As will be seen from the results, production trends were found to be influenced by rainfall variability[8]. Eqs. (3) and (4) were also estimated using OLS, and Eq. (5) estimates were derived from results of Eqs. (3) and (4).

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[6]A more representative estimate of rainfall would ideally have been computed as a weighted average, depending on the concentration of production in various parts of the country. However, this procedure was not possible due to the inavailability of disaggregated production data for the entire period. Disaggregated (district level) data were available only for the 1979–90 period, and our analysis could not have been based solely on this period because of the shortage of degrees of freedom. The procedure we adopted provides the best estimate of rainfall and its variability in Botswana, given the scantiness of data. The emperical results, which still have to be reported, indicate that the resulting rainfall estimates performed reasonaly well.

[7]Aggregating monthly rainfall figures into ploughing/planting and growing seasons may have masked within period rainfall variability. One way of dealing with this problem would have been to use monthly rainfall figures in the model. However, this procedure would have introduced too many variables into the model, leading to fewer degrees of freedom.

[8]Growth rates in rainfall for the ploughing/planting and the growing seasons were also estimated to determine if a relationship between production trends and rainfall existed.

Table 2
Parameter estimates for the growth Eq. (1)

Equation	R^2	DF
$\ln A = -199.454 \underset{(-2.4917)^{**}}{+0.1073Y} - \underset{(-2.6433)^{*}}{0.1327}(Y-1974)D^2 \underset{(-2.4637)^{**}}{+0.1510}(Y-1985)D^3 \\ {}_{(2.3806)^{**}}$	0.43	19
$\ln Q = -409.166 \underset{(-1.7103)^{*}}{+0.2130Y} \underset{(1.7554)^{**}}{0.4124}(Y-1974)D^2 \underset{(-2.5613)^{***}}{+0.5630}(Y-1985)D^3 \\ {}_{(2.9699)^{***}}$	0.40	19
$\ln(Q/A) = -209.712 \underset{(-1.1134)}{+0.1057Y} \underset{(1.1062)}{-0.2797}(Y-1974)D^2 \underset{(-2.2062)^{**}}{+0.4120}(Y-1985)D^3 \\ {}_{(2.7606)^{***}}$	0.48	19
$\ln \text{ROF} = -234.421 \underset{(2.8589)^{***}}{+0.1219Y} \underset{(2.9305)^{***}}{-0.1758}(Y-1974)D^2 \underset{(-3.1845)^{***}}{+0.1352}(Y-1985)D^3 \\ {}_{(2.0811)^{**}}$	0.36	19
$\ln \text{ROA} = -178.475 \underset{(-2.2347)^{**}}{+0.0936Y} \underset{(2.3116)^{**}}{-0.1445}(Y-1974)D^2 \underset{(-2.6875)^{***}}{+0.1316}(Y-1985)D^3 \\ {}_{(2.0802)^{**}}$	0.30	19

DF = Degrees of freedom; Y = Year; Q = Crop output; A = Crop area planted; Q/A = Crop yield; ROF = Rainfall for October through February; ROA = Rainfall for October through April.

t-values are in parentheses below parameter estimates.

***: Statistically significant at 1%.
**: Statistically significant at 5%.
*: Statistically significant at 10%.

5. Empirical results

5.1. Growth rates

Table 2 presents the estimates for model 1 equations. Growth rates for the first period (1968–1974) are given by the coefficients for year (Y). The differential growth rates for the second and the third periods are given by the coefficients for $(Y-1974)D^2$ and $(Y-1985)D^3$, respectively. If we consider the first equation, we notice that cultivated area rose by about 10.73% per annum during the 1968–1974 period, declined by 2.57% (=10.73 − 13.27) per year during the 1974–1985 period and rose again by 10.96% (=10.76 − 13.27 + 15.10) per annum during the 1985–1990 period. Table 3 provides annual growth rate estimates by period for cultivated area, output and

Table 3
Annual growth rates for the period 1968–90

Variable	1968–1974	1974–1985	1985–1990
Area	10.73	−2.54	12.55
Output	21.30	−19.95	36.35
Yield	10.57	−17.40	23.79
Rainfall			
ROF	12.19	−5.39	8.13
ROA	9.36	−5.08	8.08

yields. As seen, each of the three variables rose during 1968–1974, declined during 1974–1985 and rose again during 1985–1990 periods. Annual growth rates for rainfall (ROF and ROA) also exhibit a similar pattern (Table 3), implying that rainfall was a major contributing factor to the trends in cultivated area, output and yields.

To ascertain the performance of the variables in question over the entire period (1968–1990), a single period growth model of the form $\ln X_t = \gamma_0 + \gamma_1 Y_t + \varepsilon_t$ was specified and estimated, where γ_1 is the annual growth rate. The model estimation results are presented in Table 4. As evident therein, cultivated area rose by about 2.2% per annum during the period under review (the coefficient is statistically significant at 5%). The results indicate a statistically insignificant decrease in output of about 3.9%. Therefore, based on statistical significance, we conclude that output remained unchanged during the reference period. As evident, crop yields fell by about 6.1 percent per annum during the 1968–1990 period. The model estimates therefore indicate that, while cultivated area increased during the 1968–1990 period, this was not the case with crop output and yields, which remained unchanged and declined, respectively. Therefore, the traditional arable sub-sector performed poorly during the review period. The forthcoming analysis will empirically identify the factors

Table 4
Growth rates estimates, 1968–90

Equation	R^2	DF
$\ln A = -31.1250 +0.0219Y$ $\quad\quad (-1.6302)^* \quad (2.2704)^{**}$	0.197	21
$\ln Q = 87.2767 -0.0389Y$ $\quad\quad (1.4620)^* \quad (-1.2905)$	0.073	21
$\ln (Q/A) = -118.402 -0.0608Y$ $\quad\quad (2.6018)^{***} \quad (-2.6455)^{***}$	0.250	21
$\ln ROF = 6.7542 -0.4838$ $\quad\quad (0.3296) \quad (-0.0467)$	0.104	21
$\ln ROA = 13.9724 -0.4007$ $\quad\quad (0.7319) \quad (-0.4153)$	0.814	21

DF = Degrees of freedom; Y = Year; Q = Output; A = Area planted; Q/A = Yield; ROF = Rainfall for October through February; ROA = Rainfall for October through April.
t-values are in parentheses below parameter estimates.
***: statistically significant at 1%.
** statistically significant at 5%.
*: Statistically significant at 10%.

that have contributed to sub-sectoral trends – the poor performance of the traditional arable sub-sector.

5.2. Arable sub-sector production model

The parameter estimates and statistical measures for the arable sub-sector production model are presented in Table 5. Most parameter estimates are consistent with a priori expectations. From Eq. (3) results, it is evident that both rainfall and the implementation

of ARAP positively influenced cultivated area. It is clear from the statistically insignificant coefficient for the trend variable that cereal cultivated area remained unchanged over time. The results testify to the fact that ARAP was effective in expanding cultivated area in the traditional sub-sector, during the 1985/1986 through 1989/1990 cropping seasons. The results also indicate that the independent variables of Eq. (3) explain about 68% ($R^2 = 0.684$) of the variation in $\ln A$. The Durbin–Watson test for the cereal area equation shows no evidence of positive first order autocorrelation at a 1% level of significance (Johnston, 1988).

Eq. (4) coefficients conform to a priori expectations. All parameter estimates for this model are statistically significant, as indicated by t-statistics. As was expected, cereal yields during the reference period varied positively with rainfall for the cropping (growing) season. The coefficient for the trend variable is negative. This captures loss of productivity over time. As the same land continues to be used over time, it is likely to lose its productivity (fertility), leading to a general reduction in yields over time, since most traditional farmers do not use fertilizers.

The coefficient for the ARAP dummy is positive and statistically significant, implying that the implementation of the program has led to an increase in yields. Any of the following three factors may have contributed to this trend. One is that during the early years of ARAP, the government provided free fertili-

Table 5
Parameter estimates for the sub-sector production model, 1968–90

Equation	Constant (C)	Rainfall		Trend (T)	ARAP (D)	R^2	Adj. R^2	DF	DW
		ln ROF	ln ROA						
3	8.0003 $(10.2121)^{***}$	0.6954 $(5.1877)^{***}$		0.0117 (1.2811)	0.2380 $(1.6262)^*$	0.684	0.634	19	1.9820
4	−12.4231 $(-6.5089)^{***}$		1.8617 $(5.9934)^{***}$	−0.0779 $(-3.9505)^{***}$	0.5511 $(1.7446)^{**}$	0.759	0.720	19	2.6326
5	−4.4228	0.6954	1.8617	−0.0662	0.7891				

Dependant variables: Model 3: A = Area planted; Model 4: Q/A = Yield; Model 5: Q = Output.
Independent variables: ROF = Rainfall for October through February; ROA = Rainfall for October through April; T: Trend variable; D: Dummy variable for ARAP ($D = 0$ for 1968–1985 and $D = 1$ for 1986–90);
A: Area planted.
*: Statistically significant at 10%.
**: Statistically significant at 5%.
***: Statistically significant at 1%.
t-values are in parentheses below estimated coefficients
DF = Degrees of freedom; DW = Durbin–Watson

zer to farmers. Some traditional farmers acquired this free fertilizer and this may have led to a general increase in sub-sectoral productivity[9]. The other cause of this trend may have been the increase in draught power availability during ARAP years, especially the increase in the number of tractors. This may have allowed farmers to acquire draught power timely following the rains, leading to increased yields since planting is done while moisture is abundant. The third cause of this trend may have been the use of improved (high yielding) seeds provided to farmers for free as part of the program. Any of these three factors or their combined effect may offer an explanation for an increase in cereal yields seen during ARAP years. As seen from Eq. (4) results, the explanatory variables account for about 76% of the variation in cereal yields. The Durbin–Watson test for negative first order auto-correlation is inconclusive (see Johnston, 1988).

As noted earlier, Eq. (5) results were derived by combining Eqs. (3) and (4) results. As evident from Table 5 (Eq. (5)), output varied positively with the two rainfall variables. The trend variable coefficient indicates that output declined over time due to the loss of productivity over time. The parameter estimate for the ARAP dummy shows that ARAP had a positive impact on cereal output.

The arable sub-sector production model was used to compute and compare the predicted values for cereal area, output and yields, under ARAP and non-ARAP scenarios to determine the effect of ARAP on these variables. Table 6 presents the findings. As shown therein, ARAP led to an increase in cultivated area of about 42 214; 52 419; 78 650; 64 943; and 54 313 hectares during the 1985–1986, 1986–1987, 1987–1988, 1988–1989 and 1989–1990 cropping seasons, respectively. This amounted to an increase of about 27% each year. Cereal output rose by about 120% during 1986 through 1990 due to the implementation of ARAP. This involved an increase of about 7,108; 10 078; 49 537; 19 498 and 10 732 metric tons in 1985–1986, 1986–1987, 1987–1988, 1988–1989 and 1989–1990, respectively. Crop yields rose by about 74% each year due to the implementation of ARAP.

As indicated in Table 6, this involved an increase of about 27, 32, 104, 49 and 32 kilograms per hectare in 1985–1986, 1986–1987, 1987–1988, 1988–1989 and 1989–1990, respectively.

Figs. 1–3 provide plots of predicted values of cereal area planted, output and yield for ARAP and non-ARAP scenarios. As seen from Fig. 1, the plot of predicted values for area planted shows an upward trend for the 1969–74 period, a downward trend for the 1974–1985 period, and another upward trend for the 1985–1990 period[10]. The peak in cultivated area was realized during the 1987/1988 cropping season, when ARAP was in place. Evidently, ARAP did increase crop area during the 1986–1990 period. Fig. 2 shows that cereal output somewhat trended upwards during the 1968–1974 period. However, the trend was reversed during the 1974–1985 period. An improvement was seen during the 1985–1990 period when a somewhat upward trend occurred. Output reached its low values during the drought of the early to mid 1980s, and the highest output figure was realized in 1974. If we assess the entire period, it is evident that output generally declined. As seen, ARAP did attempt to reverse the trend during the 1986–1990 period by increasing output, but it was not that effective in doing so. Fig. 3 shows that crop yields generally trended downwards during the entire period. While ARAP significantly increased yields during the 1986–1990 period, it was not able to reverse the downward trend in yields seen during the 1968–1990 period. The lowest yields were realized during the drought years of the 1980s, and the highest figure was seen in 1974. A closer look at the three graphs indicates that the trends in area planted, output and yields are similar. As noted previously, these trends appear to have been mainly influenced by rainfall.

The ARAP-induced changes in area planted, output and yields are not by any means small. This study therefore indicates that ARAP was effective in increasing cultivated area, output and yields, implying that the program did improve rural household food

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[9]It is, however, worth noting that while fertilizer was available in the early years of ARAP for free provision to farmers, the bulk of traditional farmers did not acquire it. The reason may be that most of these farmers lacked knowledge on the utilization of this technology.

[10]Note from Figs. 1–3 that the horizontal axis is presented in calender years rather than in cropping seasons, as has been the case. This was done to simplify the graphs. It is therefore worth noting, for example, that the label 1970 represents the 1969/70 cropping season, the label 1975 represents the 1974/75 cropping season, and so on. Therefore, the labels represent the year during which output was realized.

Table 6
The impact of ARAP on crop area, output and yield

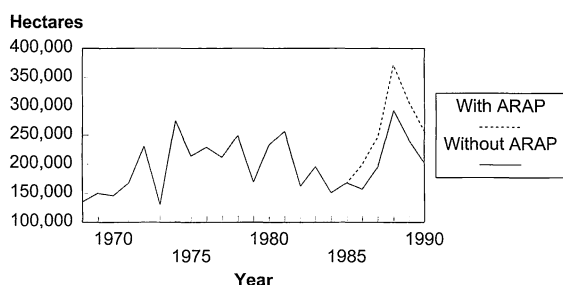| Year	Area (ha)			Output (ton)			Yield (kg/ha)		
	Without ARAP	With ARAP	Change	Without ARAP	With ARAP	Change	Without ARAP	With ARAP	Change
1986	157096	199310	42214	5916	13025	7108	38	65	27
1987	195075	247494	52419	8388	18466	10078	43	75	32
1988	292694	371344	78650	41229	90766	49537	141	244	104
1989	241681	306624	64943	16229	35727	19498	67	117	49
1990	202123	256436	54313	8932	19664	10732	44	77	32

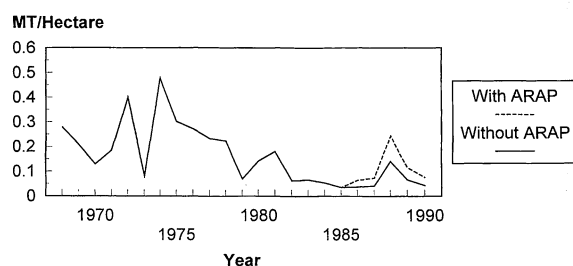
Fig. 1. Impact of ARAP on area planted.

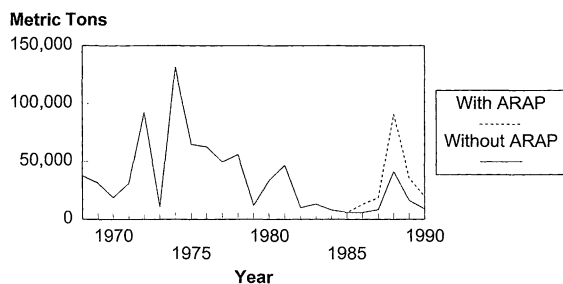Fig. 3. The impact of ARAP on crop yield.

Fig. 2. Impact of ARAP on output.

security situation and welfare. However, the model utilized in this study captured only the positive effects of ARAP. The drawbacks of the program, which have not been quantified, are discussed in depth in the forthcoming section.

6. Other effects of ARAP: a qualitative assessment

As we have noted, the present results indicate that ARAP was effective in terms of increasing crop output

and yields. This implies that the program also improved rural household food security situation and welfare. While this is the case, several criticisms have been levelled against ARAP and its variant, DRAF (Seleka and Mmofswa, 1996). One criticism is that the program was not sustainable since its implementation involved huge government outlays as subsidy to farmers. This manifested itself during the 1990–1991 and 1991–1992 cropping seasons when crop output severely declined as farmers reduced cultivated area, following the termination of the program. In view of this trend, the government introduced a modified version of ARAP, Drought Relief to Arable Farmers (DRAF), in the 1992–1993 cropping season to assist farmers to regain their production base and to improve arable sub-sector productivity. DRAF, which was ideally a continuation of ARAP, was in operation until the 1995–1996 cropping season when it operated for the final cropping season. In 1996–1997, it was reported through local media that farmers had reduced their arable activity due to the termination of this program, and output for that cropping season was expected to drastically dwindle. The present study has not captured the post ARAP production effects since crop

production statistics were unavailable for the 1990–1991 and 1991–1992 cropping seasons. Including these cropping seasons in the analysis would have provided a strong empirical basis for the conclusion that the benefits of ARAP were unsustainable.

The other limitation of ARAP and DRAF was that these programs led to unprecedented input substitution from animal traction to tractor traction. This was because, during program implementation, smallholder farmers could acquire tractor services since the government paid for such services. However, during the post program period, such as during 1990–1991, 1991–1992 and 1996–1997 cropping seasons, cultivated area (hence output) was reduced as tractor services were no longer affordable to the majority of smallholder farmers. But since these programs had operated for a long period of time, it became difficult for farmers to smoothly transit back to animal traction during the post-program period.

A related drawback was that tractor owners equated rents for their services to the amount provided by government as subsidy for cultivating the land (this may be viewed as a rent seeking activity that led to distortions of input prices). This meant that some of the benefits that were initially intended for smallholder farmers were in fact spill -over to tractor/draft power owners, some of which were from the neighbouring South Africa[11]. Even during the post-program period, tractor owners applied the same rents that were in place during program implementation. For example, during the 1996–1997 cropping season, the tractor service rent of about P120.00/ ha had not been revised. This rent would necessarily prevent most smallholder farmers from utilizing tractor services using their own funds, given low productivity in the traditional arable sub-sector. Seleka and Mmofswa (1996) reported average maize, sorghum, millet, beans/pulses, groundnut and sunflower yields of 102, 330, 102, 33, 87 and 275 kilograms /ha, respectively, during the 1979–1990 period and 1993. If we consider sorghum (the main staple) alone as an example, the yield of 330 kg per hectare would not provide an economic justification for renting-in tractor services with the current pur-

chase price of sorghum at the Botswana Agricultural Marketing Board set at P34.00 per 70 kg bag (see also Panin, 1995). This would also be the case for other crops. It is however hoped that tractor service rents would eventually transit back to their free market level since DRAF has been terminated.

7. Future challenges

The results of this study provide a solid empirical basis that the government goal of improving productivity in the arable sub-sector is not nearing realization. Instead, a reverse situation is being realized since productivity has been declining over time. Since the majority of rural households are tied to arable agriculture and depend on it for a livelihood, the challenge facing policy makers is to devise new ways of reversing the current trends in the sub-sector, if the rural household food security situation is to be improved.

Several constraints have been cited as plausible sources of low productivity levels and productivity decline in the arable sub-sector. Among these constraints are poor soil fertility, inadequate soil moisture resulting from inadequate rainfall, low adoption of improved technologies, poor farm management, inadequate farm inputs, inadequate draft power at critical times, poor access to credit, shortage of water at land areas, and insufficient knowledge and training of both extension agents and farmers (Seleka and Mmofswa, 1996; pp. 10).

Several attempts have been made by the Ministry of Agriculture to ameliorate some of these constraints, and it does not seem like such action has been translated into productivity growth. For example, constraints such as poor farm management and insufficient knowledge and training of extension agents and farmers have been addressed through training. Long-term, short-term and in-service training have been extended to extension workers. However, it does not appear that skills acquired through such training do trickle down to the farmers. Farmer training has also been undertaken through Rural Training Centres and other relevant institutions, but it appears that skills acquired through such training are not put to practical use. Therefore, the challenge facing the sector is to ensure that training offered to both extension workers and farmers is relevant to and is put to practical use by

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[11]Evidence from Mmamaereng extension area in southeastern district reveal that during the 1989/90 cropping season, 28% of the ploughing subsidy was received by households who ploughed their own land, whereas the remaining 72% was received by contract ploughers (Food Studies Group, 1990).

the farmers. A monitoring system needs to be put in place to ensure that skills acquired by extension workers are passed on to the farmers. Moreover, follow-up training of farmers may have to be done at the farmers' fields and using actual data generated from their production activities so that they could appreciate the value of being trained[12].

Deliberate efforts have to be made to promote the interaction between the Ministry of Agriculture officials and the farmers. Such interaction would be intended to promote an understanding of the farmers' constraints from the farmers' own perspectives. This will facilitate the prioritization of constraints according to their importance to the welfare of smallholder farmers, to allow government support to be relevant to the farmers' technical and socio-economic environments. It would not assist smallholder farmers, for example, to have access to credit for acquiring farm inputs, if they have no knowledge about input use or they are not keen on utilizing such inputs. If this were the case, a more appropriate action would be to begin with promoting technology diffusion.

Currently, there is a stock of improved technologies that have been proven, particularly through on-station research, to be technically feasible to the country and have been recommended for adoption. However, the extension service has not been very successful in transferring those technologies to the farmers. The immediate challenge therefore is to ascertain why farmers are not keen on adopting such technologies. It may be that such technologies are not suited to the farmer's socio-economic and technical environments. Therefore, the farming systems research and extension approach, which has now been embraced as an agricultural development strategy in Botswana, has to be strengthened to promote greater coordination between research, planning, extension and the farmers.

There is currently a substantial yield gap between traditional and commercial farmers. Crop production data for the 1979 through 1990 period and 1993 revealed that average maize, sorghum, millet, beans/

pulses, groundnuts, and sunflower yields in kilograms per hectare were 66 (723), 108 (525), 90 (230), 47(224), 110 (602) and 119 (473), respectively, for traditional (commercial) farming (Seleka and Mmofswa, 1996). This means that crop yields in commercial farming were at least 2.5 times those for traditional farming (in the case of millet). The maximum yield gap during the period was for maize where yields in the commercial system were about 11 times those in the traditional system. Research needs to be undertaken to establish why this yield gap does exist, particularly for those farmers who operate under similar climatic environments. Such research would need to be a comparative analysis of the socio-economic settings under which the two production systems operate. If it is found, for example, that the commercial system is more profitable than the traditional system, efforts have to be made to bring about necessary conditions for increasing yields in the traditional system to the level of commercial system yields. Given that about 90% of cultivated area is occupied by the traditional system, this may yield significant increases in arable agricultural production.

One of the agricultural policy objectives of government is to promote diversification of agricultural activities into non-traditional areas of production such as horticulture, poultry (broiler and egg production), piggery and agro-forestry. To achieve the diversification objective, the government introduced the Financial Assistance Policy (FAP) as a funding source for farmers who intend starting productive enterprises. However, FAP support to rural households, particularly those tied to traditional arable farming, has been minimal. Perhaps this has been due to the level of expertise required to qualify for support under the scheme. Support under FAP may have to be continued to promote transformation of the agricultural sector, but supported projects would require to be closely and continuously monitored to promote their continuity and sustainability.

8. Concluding remarks

The intent of this study was to assess the performance of Botswana's traditional arable agriculture for the 1968–1990 period. The results indicate that the sub-sector performed poorly during the review period.

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[12]For example, farmer training on record keeping may be less effective if it is done at a rural training centre where it is based on hypothetical data. However, a follow-up training undertaken at the farmers' fields where it is based on the farmers' data may allow the farmers to better appreciate the value of record keeping as a farm management tool.

Cultivated area registered an annual growth rate of about 2.2% during the 1968–1990 period. However, crop output remained unchanged and yields declined by 6.1% per year during the same period.

The sub-sectoral production model indicates that cultivated area, output and crop yields depended on the level of annual rainfall. Therefore, rainfall was found to be the main input in the traditional arable farming. This model also indicates that ARAP led to an expansion in cultivated area, output and yields of about 27%, 120% and 74% (respectively) as a direct impact of implementing the program. This implies that ARAP was effective in improving rural household food security and welfare.

The empirical model of this study only captured the positive effects of ARAP. Several drawbacks are worth noting. Firstly, ARAP was not sustainable, since it involved huge government outlays as support to farmers. When the program was terminated during the 1990/1991 and 1991/1992 cropping seasons, farmers reduced their arable activity. As a result, the government introduced a variant of this program (Drought Relief to Arable Farmers (DRAF)) in the 1992/1993 cropping season to help farmers regain their production base. DRAF was terminated during the 1996/1997 cropping season, and arable activity was reduced as a result. Therefore, program effects were unsustainable.

The other limitation of ARAP was that it led to input substitution away from animal traction to tractor traction. This had a negative impact since when the program was terminated, farmers could no longer afford hiring-in tractor services. Moreover, they could not smoothly transit back to animal traction since the program had operated for too long. A related drawback of ARAP was that tractor owners equated rents for their services to the subsidy provided by government for cultivation. This meant that the initially intended direct transfer of income to farmers was hardly realized.

The sub-sectoral model also revealed that crop yields varied negatively with time, implying that the sub-sector saw productivity losses over time. This is a challenge that policy makers have to deliberately address. There is an urgent need for government

to devise new and sustainable ways of reversing the current trends, if the objective of improving rural household food security has to come near to realization.

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