Economics, yield, and ecology: A case study from the South African tomato industry

Stephanus Malherbe[a,*], Diana Marais[b]

[a] ZZ2, PO Box 19, Mooketsi, 0825, South Africa.

[b] Department of Plant Production and Soil Science, Faculty of Natural and Agricultural Sciences, University of Pretoria, Pretoria 0002, South Africa.

*Corresponding author: stephanusmalherbe@gmail.com

Author description:

Stephanus Malherbe is a Senior Researcher with the largest tomato producer in South Africa, ZZ2, PO Box 19, Mooketsi, 0825, South Africa. E-mail: stephanusmalherbe@gmail.com.

Diana Marais is with the Department of Plant Production and Soil Science, University of Pretoria, Pretoria, South Africa.

Abstract

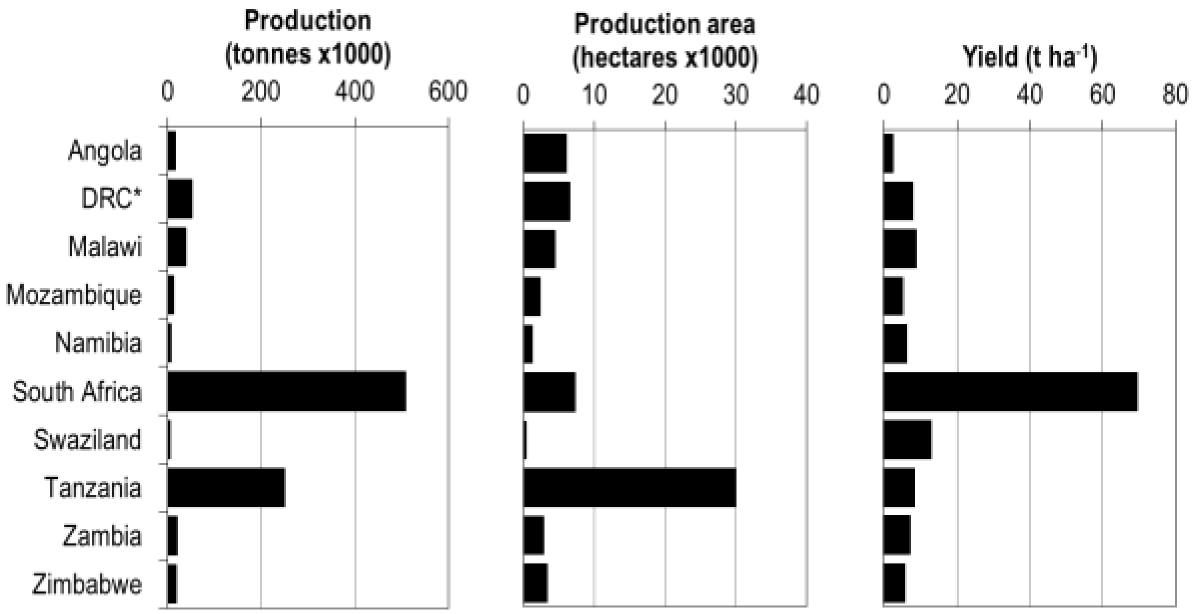
A clear tomato yield gap exists in Southern Africa. Understanding the economic crop production factors is a necessary prelude to any discussion of ecological sustainability. The objective of this study was to evaluate the economic factors that influence the sustainability of open field tomato production. We compared detailed tomato production costs from six international studies to data from the largest commercial tomato producer in South Africa. The Environmental Impact Quotient (EIQ) was used to demonstrate the interactions between economic and agro-ecological constraints. Economic pressures are forcing tomato producers to intensify production, which underscores the need for the continued development of ecologically sustainable tomato production systems. The findings of this study will benefit policy development in support of sustainable food security in the rural areas of Southern Africa and beyond.

Keywords: costs; environmental impact quotient; food security; sustainability; prices.

Introduction

The tomato is an important vegetable with a range of reported nutritional and health benefits. It is cultivated on every continent except Antarctica. Global tomato production (tonnes) has grown by 47% from 2001 to 2011, with Asia (85%) showing the strongest regional growth (FAOSTAT, 2014). Tomato production in the Southern African Development Corporation (SADC) region also demonstrated growth over the same 2001-2011 period (+20%). South Africa is the dominant producer in the SADC region, growing 54% of tomatoes on 11% of the total cropped area (Figure 1). Despite ranking 35th in the world based on total tonnage in 2011, South Africa remains a major regional tomato producer in Sub-Saharan Africa (Figure 1). However, a substantial tomato yield gap exists within the SADC region even though

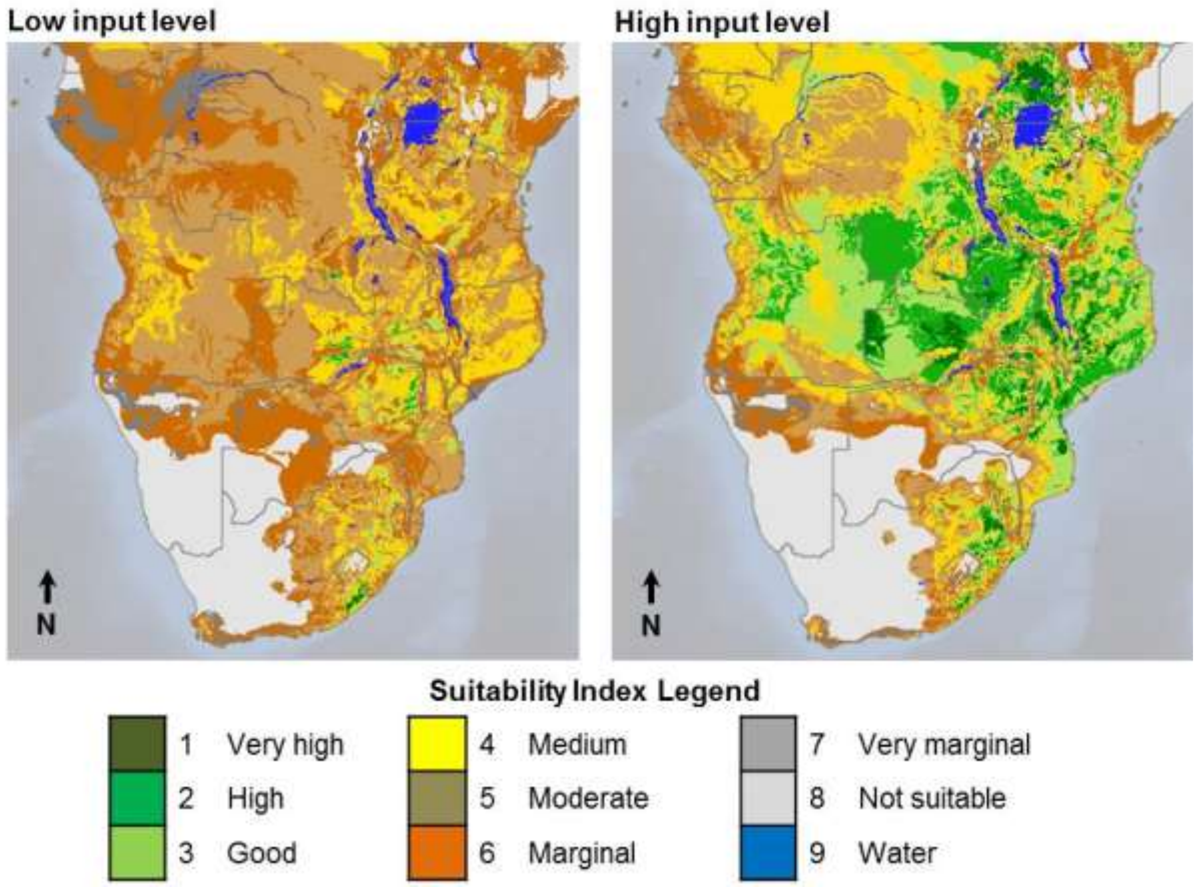
Figure 1 Tomato yield gap in the SADC region in 2011 (FAOSTAT, 2014). Note: DRC = Democratic Republic of the Congo; the islands of Mauritius and Seychelles were excluded from the analysis.



several countries have climate conditions suitable for open-field tomato production (Figure 2). Understanding the reasons behind tomato crop failures and successes in South Africa could boost tomato production in the fast-growing tomato markets of Angola, Mozambique and Zimbabwe, thereby improving food and nutrition security for smallholders and the population in general.

Several options are available for addressing the tomato yield gap in Southern Africa. However, crop-specific economic and practical implications associated with potential

Figure 2 Crop suitability index for rain-fed tomato production in the SADC region based on low (A) or high (B) input level for 1961-1990 baseline period (GAEZ v 3.0, www.gaez.fao.org, accessed 23 December 2013). High input level assumes best technology, nutrient and crop management practices are implemented; low input level assumes minimum inputs are utilized (Fischer *et al*, 2002).



solutions may limit adoption by growers. For example, the potential of compost as a soil health management option is widely acknowledged. Composts contain nutrients that can improve crop productivity especially where synthetic fertilizers are not readily available to subsistence growers. Although tomato yield improvement as a result of compost usage have been reported in the scientific literature, the magnitude of the yield improvements often falls short of yields expected by commercial growers (e.g., Bulluck *et al*, 2002; Sheahan *et al*, 2012). Experiences in Southern Africa have shown that subsistence growers benefitted from such research outcomes (Masaka *et al*, 2013). Commercial tomato growers however are less excited about adoption of compost as the only means to improve crop productivity. The world is looking toward the commercial agriculture sector to continue to provide more food per hectare. It is important for policy and applied research practitioners to understand why it seems the commercial agriculture sector does not adopt sustainable production technologies with more enthusiasm.

The objective of this paper is to highlight the economic factors that govern the sustainability of the South African tomato industry. This is a necessary prelude to a discussion of the biophysical limitations of tomato cultivation in Southern Africa and its agro-ecological implications. Furthermore, this economic foundation will inform the general discourse on exactly what sustainable tomato production means for producers in the greater Southern Africa region and beyond.

Meta-analysis of tomato production costs

A literature review of fresh market, open-field, medium-sized cultivar tomato production studies was performed to identify the agronomic megatrends that governed high- and low-yield scenarios in organic, conventional and integrated open-field, medium-sized cultivar, fresh-market tomato production systems. A meta-analysis was performed on the literature extracted from ScienceDirect and Google Scholar with the following keywords: tomato, organic and conventional. Several hundred publications were retrieved and evaluated for completeness in terms of the agronomic criteria, but only six detailed reports on tomato production costs were found. The production costs were adjusted to 2013 US\$ ha^{-1} from US\$ ha^{-1} in the publication year to account for relative inflation. Profit was calculated as follows:

Profit = (gross income – gross expenses)/gross expenses)*100 (1)

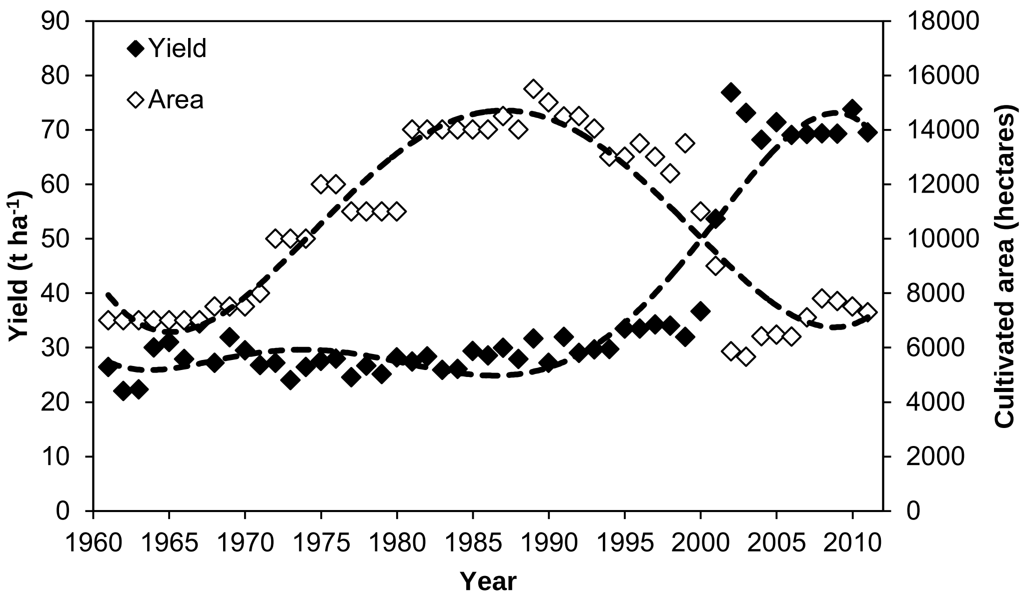
Global and national tomato production statistics were obtained from FAOSTAT, the South African Department of Agriculture, Forestry and Fisheries and Statistics South Africa. In addition to this, long-term production cost, yield and tomato pricing data were obtained from the largest commercial tomato producer in South Africa (www.zz2.biz). Open field tomato production activities are centred on the town of Mooketsi, Limpopo province, South Africa (23^o36’5.95’S; 30^o5’37.02’E). Detailed records on all aspects of crop management (i.e., the use of biocides, pesticides and herbicides) were obtained from these commercial tomato producers in the Limpopo Province of South Africa. This information was used to calculate the ecological impact of cultivation events using the 2012 version of the Environmental Impact Quotient (EIQ) model (Kovach *et al*, 1992). The EIQ is a composite indicator for calculating the relative impact of agricultural pesticides on the consumer, worker and ecosystem; only the ecosystem impact component was used in this study. Time-series and Correlation and Regression Tree (CART) analyses were performed in R (packages *ts* and *ctree*; www.r-project.com). Where mentioned in the text, statistical significance was determined with the Kruskal-Wallis test ($\alpha = 0.05$) using PAST (Hammer *et al*, 2001); error bars represent the standard error of the mean in all figures.

Results and discussions

Tomato cultivation in South Africa

Access to improved cultivars in the early 2000's revolutionized tomato production in South Africa. The introduction of indeterminate cultivars allowed for sustained high-intensity production (+67% yield) on 47% less land (Figure 3). Access to agrotechnology (knowledge, synthetic inputs, information technology) - not long-term climate change - further enhanced productivity where tomato cultivation was already successful.

Figure 3 Tomato production trends in South Africa from 1961-2011 (FAOSTAT, 2014). Note: Dotted lines are polynomial trend curves.



omatoes are grown in all provinces of South Africa. Covered cultivation occurs near the major metropolitan areas in Gauteng, Kwa-Zulu Natal, and Eastern-Cape and Western-Cape provinces, but 75% of open field production occurs in the Limpopo Province (Department of

Agriculture, Forestry and Fisheries, 2011). The last agricultural census reported that R630 million of revenue was generated from only 4,523 hectares of tomatoes in the Limpopo Province (Statistics South Africa, 2007). The census also indicated that tomatoes commanded a higher average price per tonne (ranked 2nd after groundnuts), and this, together with high relative yields of 58.3 t ha^{-1}, netted tomato producers an average income of close to R139,000 ha^{-1} (2.5-fold higher income than potatoes).

Thus, apart from a suitable climate, the economic success of tomato production in the Limpopo Province contained the following elements: high yield, high price, and high total production volumes. Tomato producers generated income from the sales of tomatoes from either selling them as fresh produce (high quality) or for processing (low quality). The best source of income for tomato producers in South Africa is the fresh produce consumer market.

A review of open field tomato production costs

The literature on detailed post- 2000 open field fresh-market tomato production costs is scarce; available sources refer mostly to tomato production studies from the United States and Turkey and one study from India, for a total of six studies. Data from the South African tomato producer were included for comparison. Production costs and reported profits varied substantially between the reports (Table 1). Tomato producers from the Northwest United States reported the highest production costs per hectare and also the highest profit due to very high market prices (Galinato *et al*, 2012). The median profit for the data reported in Table 1 was 30%, but this value must be interpreted with care. For example, the study by Bhardwaj *et al* (2011) reported a 34% profit for tomato producers in rural India, but the \$234 ha^{-1} profit was 16.5 times lower than the median profit of \$4,000 ha^{-1} calculated from the publications reviewed. The \$2,417 ha^{-1} profit (64.4%) reported for Turkish tomato producers was 1.65 times lower than the median profit (Engindeniz, 2007). Additionally, the 124% profit reported by Galinato *et al* (2012) did not compensate for marketing and advertising costs associated with supplying a packaged product to distant urban markets, as was the case with the South African producer.

Labour and marketing costs dominated the cost structure in most of the studies considered here (Table 2). The South African production cost situation was similar to the global perspective, aside from the high marketing costs. The study on organic tomato production in Florida (Table 1) reported a net loss due to low overall production (12 t ha^{-1} yield) and high labour costs (Sheahan *et al*, 2012). In another study, the organic and low-input production systems were less profitable that the conventional system due to high labour costs (Clark *et al*,

Table 1 Comparison of production costs (ha^{-1}) and profits per hectare (\$ ha^{-1}) for open field fresh-market tomatoes production systems.

Region (year)	**Cost (ha^{-1})**	**Income (ha^{-1})**	**Profit (\$ ha^{-1})**	**Price (t^{-1})**	**Profit**	**References**
India (2011)	$717	$960	$243	$80	34%	Bhardwaj *et al* (2011)
South Africa (2005)	$15 937	$20 160	$4 223	$252	27%	
South Africa (2011)	$31 826	$35 600	$3 774	$445	12%	
Turkey (2010)	$3 249	$5 896	$2 647	$112	81%	Keskin *et al* (2010)
USA California (2007)	$34 276	$45 500	$11 224	$1 400	33%	Stoddard *et al* (2007)
USA Florida (2009)	$47 530	$55 130	$7 600	$1 313	16%	VanSickle *et al* (2009)
USA Florida (2012)	$38 170	$18 450	$-19 720	$1 230	-52%	Sheahan *et al* (2012)
USA Northwest (2012)	$67 855	$151 800	$83 945	$4 464	124%	Galinato *et al* (2012)
Descriptive statistics						
25th percentile	$12 765	$15 312	$2 046	$217	15%	
Median	$33 051	$27 880	$4 000	$838	30%	
75th percentile	$42 850	$50 315	$9 412	$1 357	30%	

1998). While the actual agronomy-related costs represented 26% of total costs per hectare, the cost-savings research reported in the literature often focuses on optimizing pesticide application, fertilizer and water usage, planting density, pruning practices and soil quality (Creamer *et al*, 1996; Chellemi *et al*, 1997; Çetin and Uygan, 2008; Argerich *et al*, 2013; Massa *et al*, 2013; Qiu *et al*, 2013). Indeed, processing tomato production costs in the USA decreased with the transition from manual to mechanical harvesting from 1963-1967 (Just and Chern, 1980). This trend was global and is expected to continue as labour costs increase (Dadomo, 1994). Increased labour demand for weeding was a major obstacle to the adoption of conservation agriculture in parts of Africa (Giller *et al*, 2009). From the information presented in Table 2, it was clear that potentially greater cost savings could be incurred by optimizing labour and marketing costs. However, such efforts were likely to strain labour relations and local social cohesion.

The South African example illustrates the typical economic challenges of tomato producers in general. The production costs per hectare doubled within six years, but the profit margin decreased 2.25-fold (Table 1). The contribution of pest control (3%) was similar to values reported for tomato production systems in Turkey (4.1%, Engindeniz, 2006; see also Table 2). Combined plant nutrition and pest control costs (9-10%) were lower than similar costs reported for tomato production in the USA (15%, Bloem and Mizell, 2000; see also Table 2). Therefore, increased production costs could not be attributed to a single cost factor, but were a function of changing global and local socio-economic factors. For example, for every percentage increase in oil price, agrochemical and fertilizer prices increased by 0.24 and 0.25%, respectively, and this effect lasted for 28 months after the initial oil price shock (Babula and Somwaru *et al*, 1992).

In summary, the data gathered from the literature indicated that open field fresh-market tomato production was a labour-intensive process. Actual agronomy-related expenses – crop nutrition, protection and cultivation – represented 25% of the total costs. Nevertheless, the break even yields calculated for South African tomato producers were 2.3 and 2.6 times higher than the median breakeven yield calculated for the producers analysed for this study and were 20 times higher than the breakeven yield calculated for Turkish tomato farmers (Engindeniz and Cosar, 2013). Despite increasing production costs, producer profit remained unstable due to tomato price volatility (MacDonald, 2000). South African tomato producers, therefore, have three options for increasing profits and remaining economically sustainable:

Table 2 Comparative breakdown of production costs per hectare (%) for open field fresh-market tomato production systems.

Region (year)[1]	**Wages**[2]	**Fertilizer**	**Pesticides**	**Seedlings**	**Overheads**	**Marketing**[3]	**Other**[4]
India (2011)	20%	8%	8%	7%	11%	43%	3%
South Africa (2005)	33%	8%	4%	2%	11%	25%	17%
South Africa (2011)	33%	7%	3%	4%	12%	25%	15%
Turkey (2010)	40%	11%	5%	4%	11%	0%	28%
USA California (2007)	63%	4%	7%	10%	8%	7%	0%
USA Florida (2009)	49%	8%	9%	3%	9%	9%	14%
USA Florida (2012)	57%	25%	0%	3%	0%	15%	0%
USA Northwest (2012)	67%	9%	1%	3%	9%	9%	3%
Descriptive statistics							
25th percentile	33%	8%	3%	3%	9%	8%	2%
Median	44%	8%	4%	4%	10%	12%	9%
75th percentile	60%	8%	5%	4%	10%	20%	14%

1. See Table 1 for references to studies.

2. Wages included temporary and permanent staff.

3. Marketing costs included packaging materials and transport costs to markets.

reduce production costs, increase yields, or secure high prices. In the following section we focus on why tomato pricing encourages intensive tomato production.

South African tomato prices

Tomato production in South Africa appears to be a lucrative business given the above-average prices secured on local markets when compared to other important crop types. In a mixed-rotation farming experiment in the USA, the economics of the different farming systems tested were strongly influenced by the costs and profits associated with the tomato production component (Clark *et al*, 1999). In a similar study in Ohio (Northwest United States), the conventional system was more costly to operate than the sustainable technologies tested, but the conventional system was mostly superior in terms of profitability because of its higher yield and quality (Creamer *et al*, 1996).

South African tomato price trends were in line with the international trend, but international tomato prices were substantially higher than prices offered by the South African consumer (Figure 4). An international tomato trade modelling study showed that Africa remained the cheapest place to produce tomatoes, but distance from the large consumer markets and 'tariffs' forced its prices, and the prices of Asia and Latin America, to be on par with tomato producing regions in the developed countries (Guajardo and Elizondo, 2003). However, at the local South African level, annual and seasonal price variation was at times substantial and indicated greater volatility in local tomato pricing dynamics since 2006 (Figure 5). Long-term forecasting indicates that the South African tomato prices are likely to stabilize and even increase slightly, provided that the fundamental socio-economic drivers of tomato consumption do not change. Economic sustainability was achievable provided that production costs were low, the market price was high and the agronomic performance was good.

The fact that the price of tomatoes was sensitive to differences in quality grades further complicated the producer's income situation (Figure 6). Tomato fruit size also has a major influence on price (e.g., Abdul-Baki *et al*, 1992). In South Africa, the prices of different quality grades for large-variety tomatoes differed significantly ($P < 0.01$), which means that the distribution of quality grades within the marketable yield profile could exert an important influence on the final gross income (Figure 7). Customer preferences determined which varieties would be in demand, and this, in turn, motivated the producer to pursue production of specific cultivar lines. For example, in the United States, the marketable yield of hybrid varieties was higher than heirloom varieties, but heirloom varieties were in greater demand due to consumer preference, with better resulting economic benefits (Rogers and Wszelaki, 2012). American consumers preferred fresher locally grown tomatoes over more mature produce from distant markets (Bierlen and Grunewald, 1995). It is important to guard against an over-emphasis on high quality produce. In developing countries, especially in rural areas, demand for high quality produce may be low due to unavailability, with the supply of affordable food being more important; therefore, 'lesser' qualities would be accepted by poor

Figure 4 South African tomato price dynamics in comparison to global price trends (FAOSTAT, 2014).

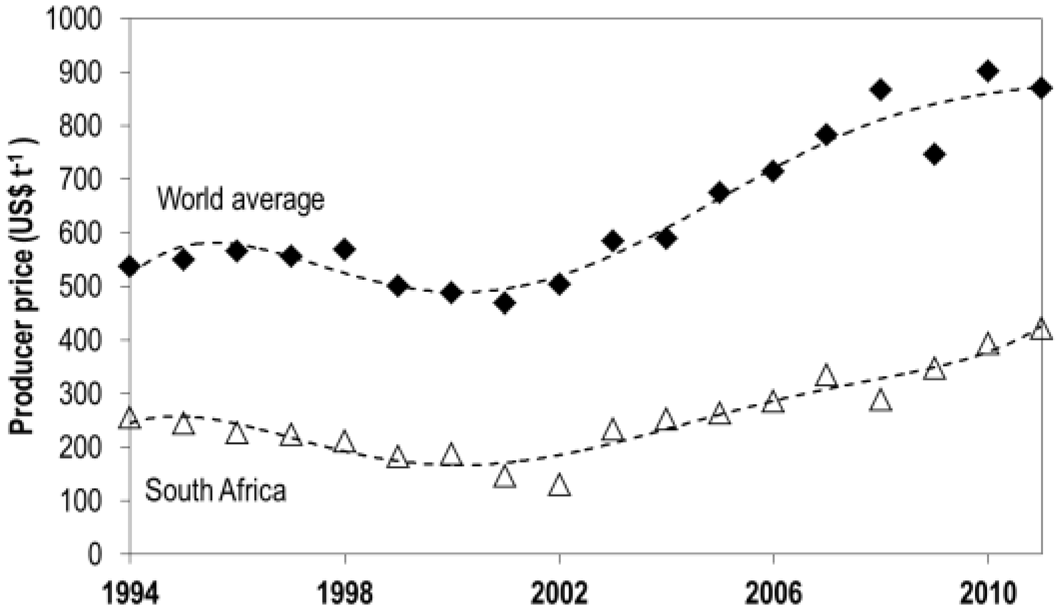


Figure 5 Time series analysis of medium variety tomato prices for South Africa showing the main trend and medium-term forecast. Note: CI = confidence interval.

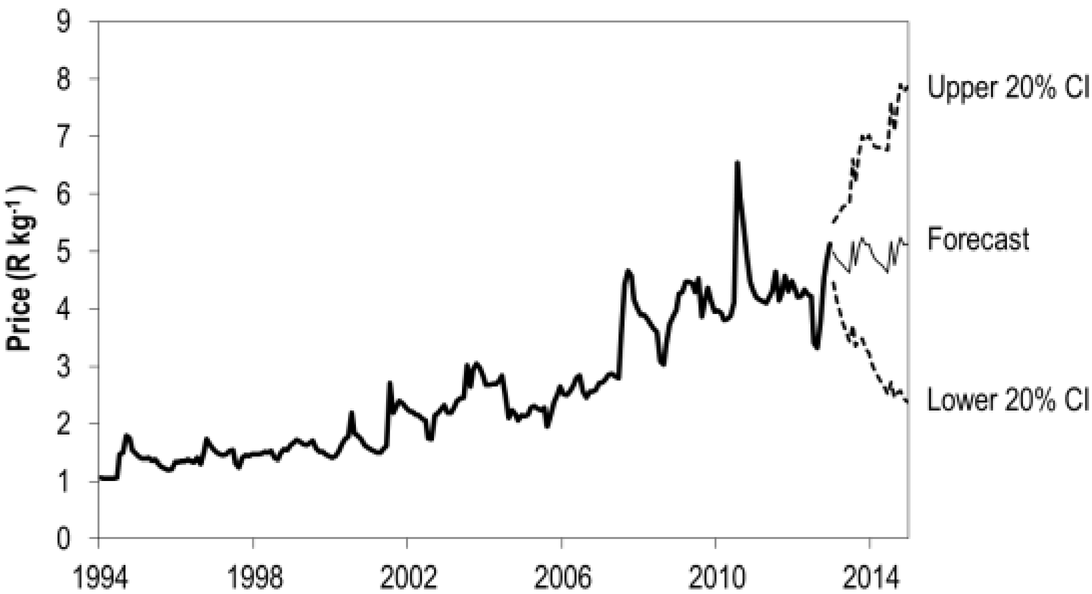


Figure 6 South African National Fresh Produce Market tomato prices in 2011 according to quality. Note: LSL = long shelf life fresh salad tomato variety; percentages indicate difference in price from Grade 1 price; error bars = standard error of the mean for 2011.

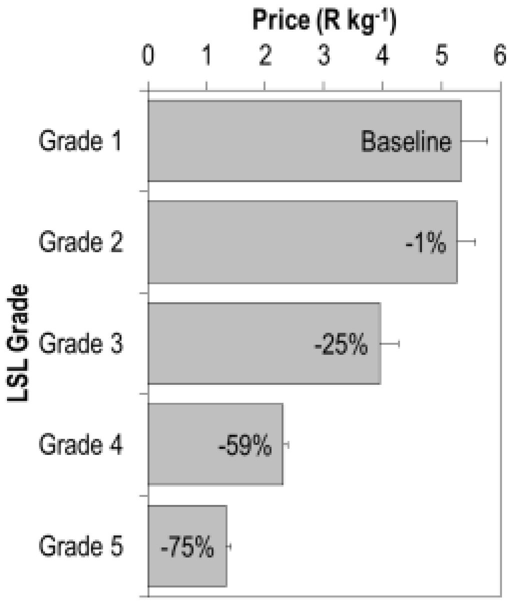
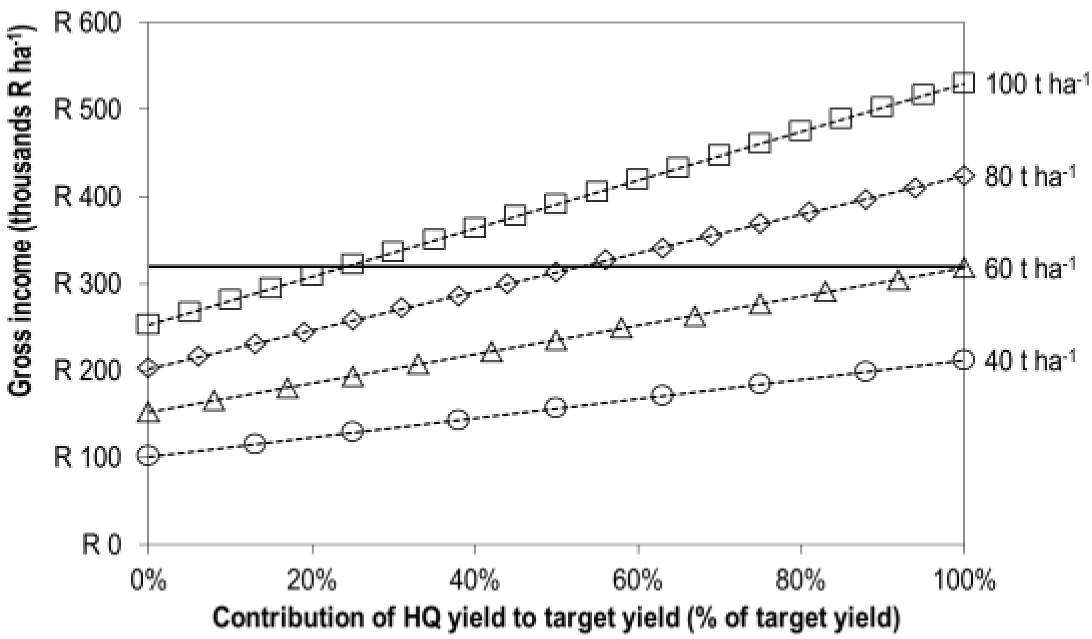


Figure 7 Contribution of quality grades to overall economic sustainability of tomato production. Note: Horizontal line is the R320, 000 ha^{-1} breakeven point used for open-field fresh-market tomato production in South Africa in 2011. Gross incomes were calculated from 2011 grade-specific prices (Figure 6). HQ Yield = High Quality Yield (Grades 1 + 2); LQ Yield = Low Quality Yield (Grades 3+4+5).



consumers (Cadilhon *et al*, 2006; Dixon and Isaacs, 2013). Even in a developed country context, American consumers were less concerned about the production method (organic vs conventional), but were more concerned about the tomato type and price (Simonne *et al*, 2006).

Production volumes are influenced by climate and agronomic factors, which eventually influence tomato prices. For example, Mexican producers supply the American and Canadian markets, but acute shortages in the United States caused by climate-related crop failures created local shortages in Mexico, which caused prices to rise. The opposite occurs with over production in the American region, leading the local Mexican prices to decrease sharply because of the inability of Mexican producers to compete with locally produced American tomatoes (Humphries, 1993). Pricing issues dominated the resulting 'tomato wars' between American and Mexican producers (Thompson and Wilson, 1996; Girapunthong *et al*, 2004). The supply and demand fluctuations in Mexico and the USA were caused by climate shocks and resulted in price volatility. A similar situation was reported elsewhere in the world (Garg *et al*, 2008; Tadesse *et al*, 2014). In India, producers bore the brunt of price fluctuations: 'When there is huge production, price of tomato reduced very sharply. At that time producers bears huge losses because they even could not cover their production cost' (Barhdwaj *et al*, 2011). For this reason, some have called for moderate tomato price intervention/stabilization to safeguard emerging producers against marketplace turmoil (Jayne, 2012). In South Africa, the minimum wage for farm workers increased by 52% in March 2012, which generated calls for set minimum market prices for agricultural products. Indeed, rice price stabilization was an important aspect of rural development in Asia (Dawe and Timmer, 2012) and was recommended for maize in Sub-Saharan Africa (Galtier, 2013).

Non-climate factors also influence tomato prices at the local level. The current global economic crisis impacts food prices and consumer buying power, which results in altered food acquisition behaviour (Regmi and Meade, 2013). Despite the importance of climate in determining agronomic performance and market dynamics by implication, additional non-crop related factors can also limit tomato production, such as unexpected wage increases, urban pressure on traditional tomato growing regions, and competition from other supply regions (Weliwita and Govindasamy, 1997). This high degree of uncertainty influences the economic viability of both the organic and conventional tomato producer (Lien *et al*, 2007). Market share, management system philosophy and economies of scale were non-agronomic factors that improved the resilience of vulnerable farming enterprises (Lien *et al*, 2007;

Pannell *et al*, 2014). Producers responded by reducing risk (through cost reduction), increasing productivity (production process optimization) and pursuing specific market opportunities (niche exploitation) (George, 2013). However, the pursuit of profit at the expense of ecosystem 'health' remains a controversial issue.

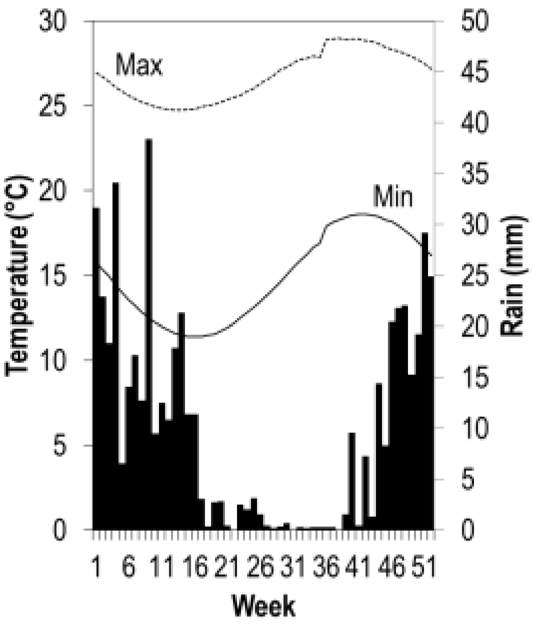
Economy versus ecology

Out-of-season supply is an important factor that encourages tomato producers to persist with unsound agronomic or ecological activities (Vawdry and Stirling, 1996; Peillón *et al*, 2013). In the 1990's, American and Mexican tomato producers worked towards multi-season supply by having geographically distributed production centres that allowed for the exploitation of local climate conditions for continuous supply (Thompson and Wilson, 1996). In Zimbabwe, tomato production in the rainy season was associated with high fungicide usage to prevent crop failure, but the rainy season crop secured prices 10 times higher than tomatoes produced during the dry times of the year (Cooper and Dobson, 2007). Manipulation of irrigation could allow for earlier fruit ripening, thereby enabling an early harvest and providing the producer with the ability to avoid competitors when tomato prices are still high (Topcu *et al*, 2007). Likewise, Turkish producers were encouraged to first 'find their markets before they plant the first seed' (Engindeniz, 2007). In China, irrigation-related cost thresholds were relaxed when prevailing tomato prices were lucrative (Zheng *et al*, 2013). Abdul-Baki *et al* (1996) investigated the use of cover crops to provide sustainable solutions to intensive tomato production methods. They found that cover crops extended the growth season by three weeks, with 40% of the marketable yield being harvested in that extended time period, whereas the control treatments ceased to yield at that time. This meant that distant markets, with traditionally higher prices at the particular time of the year, could be serviced with substantial economic returns.

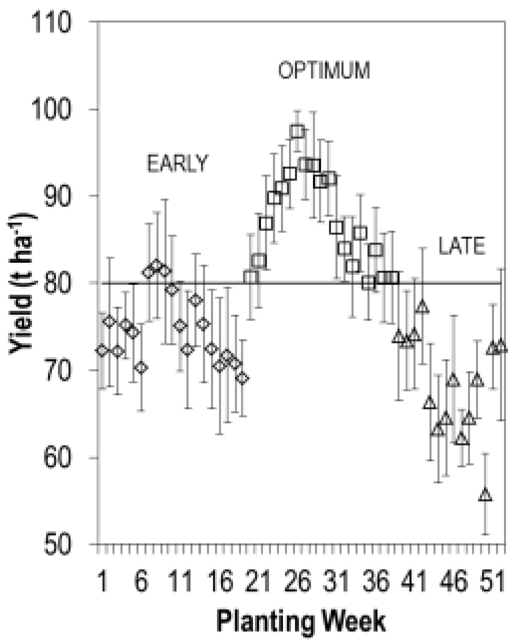
The lure of high tomato prices also convinced South African tomato producers to persist with agronomic activities within a very risky climate window. In the Lowveld agroecological zone of South Africa, the summer production season starts after 39 weeks into the year (late September) and is characterized by summer rainfall, high temperatures and humidity (Figure 8a). The marketable yield and fruit quality are severely affected as a result (Figure 8b). The combination of these hostile climate conditions determines the onset and intensity of physiological stress and below- and above-ground diseases. Producers are forced to intensify pest- and disease-control programs in this planting window. The EIQ (ecology) score for late

Figure 8. The interaction between climate (A) and marketable yield (B) in the Lowveld agroecological region. Note: The difference in yield between planting times (early, optimum and late) was significant (Kruskall-Wallis $P < 0.001$). The horizontal line on (B) indicates the 80 t ha^{-1} breakeven yield.

A



B



planting times increased by 51.6% from a mean of 72.1 to 109.4 ($P < 0.001$) (Figure 9). Therefore, the ecological footprint of the pest- and disease-control programs increased significantly as producers attempted to maintain high yields in the climatically challenging planting window. The duration of rotations were reduced because transport costs forced producers to concentrate production activities close to packaging facilities. Planting in fields with known soil-borne pest and disease problems exacerbated the situation further.

In this example, the belief among tomato growers that planting tomatoes in a difficult climate window was necessary to secure high prices had merit (Figure 10). Although data analysis revealed that tomato prices were extremely volatile in the short-term (up to +/- 20-30% for any given week), an above-average price tendency existed when fields planted in late planting times were harvested 15-25 weeks later in March and April of the following year. The cost structure of 2005 allowed for profitable farming at low yields; thus, it was worthwhile to persist with late plantings and incur the resultant negative ecological impact. However, from 2011 onwards, this was no longer the case. Production costs doubled and market prices remained between R4 kg^{-1} and R5 kg^{-1} on average (Figure 5), thus making any tomato farming activity in the late planting time unprofitable. As a result, these producers no longer

Figure 9 Influence of planting time on ecosystem impact quotient of weekly synthetic pest- and disease-control interventions. Note: The mean quotient for late planting times (white bars) differed significantly (Kruskall-Wallis P < 0.001) from the early and optimum planting times respectively (grey bars).

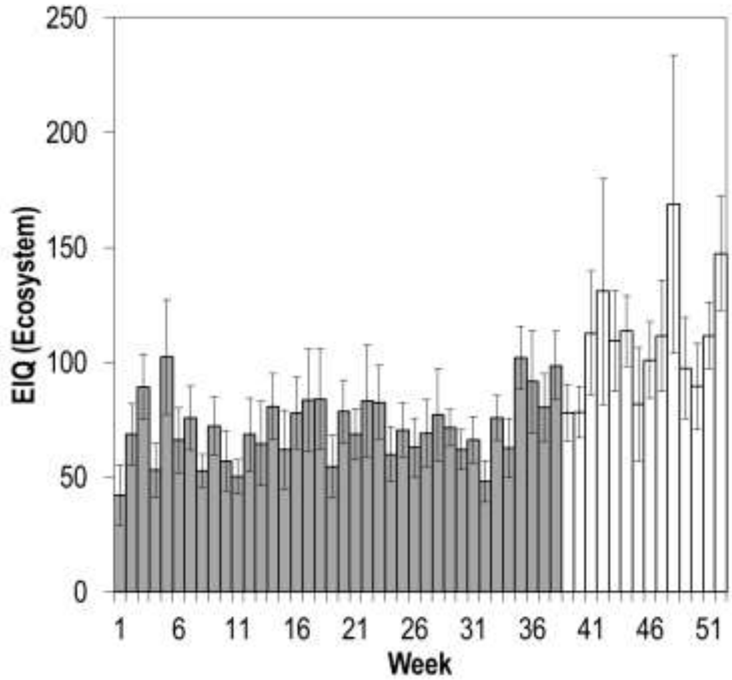
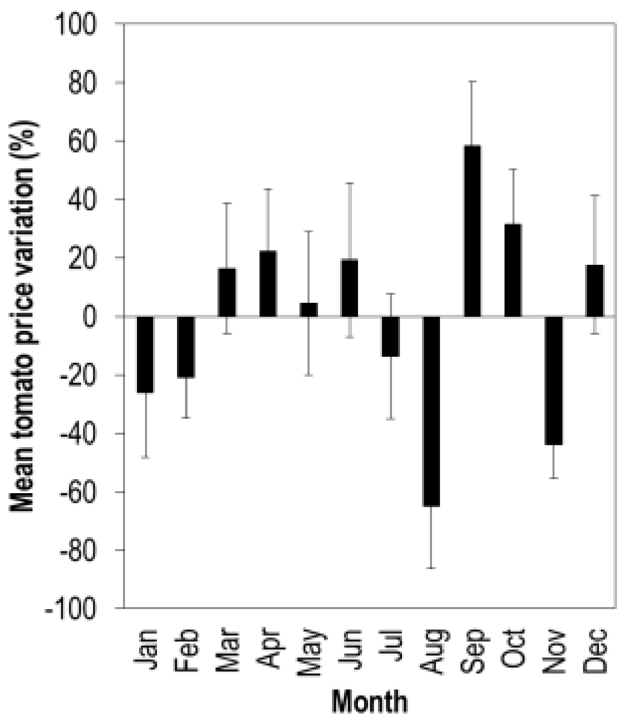


Figure 10 Tomato price variation from the annual average for the period 1989-2013.



utilized the late planting period for economic gain in the Lowveld bioregion. However, the economic incentive remains strong, which means these producers are likely to exploit the late planting window in a different agroecological zone in conjunction with reduced ecosystem impact protected cultivation technologies. In this example, increased economic stress (i.e., increased production costs and stable prices) had an unexpected ecological benefit.

Lessons for the global tomato-producing community

Intensification of tomato production is a global phenomenon and is fuelled by different driving forces. The influence of production costs for open field tomato production has been reviewed, but the growing demand from consumers is another factor that needs to be considered. The rapid spread of supermarket outlets in rural areas of Latin America increased the number of potential tomato consumers, thus encouraging the intensification of existing tomato production systems (Reardon and Berdegue, 2002). This trend was similar in other developing regions of the world for agricultural commodities in general (Reardon *et al*, 2003; Louw *et al*, 2007). As a result, supermarkets were becoming major stakeholders in the food production network (Dolan and Humphrey, 2000; Emongor and Kirsten, 2009). Indeed, supermarket tomato price fluctuations were a function of competition between supermarkets during peak demand times, while farm-side input cost fluctuations had very little influence on the retail price (MacDonald, 2000). As production costs increase and market prices stabilize – a situation known amongst economists as ‘stagflation’ – the intensification of production is likely to become the norm in future. This study regarding South African tomato producers is a case in point. The quest for increased yields is likely to come at the expense of ecological and social sustainability, with the increased pressure on soil and water and the agrolandscape and workforce. Relatively high tomato prices encourage the pursuit of profit and highlight the economic cost of failure.

Although marketing activities improve the customer value proposition, the producer has little influence on actual price discovery dynamics. Price premiums could be secured by providing high quality products to niche markets (e.g., cherry tomato varieties) and other forms of differentiation from competitors (e.g., ‘nature-friendly’, ‘organic’ or ‘socially responsible farming’ labels; Creamer *et al*, 1996; Poudel *et al*, 2001; Lien *et al*, 2007). However, the producer has a high degree of control over the crop’s agronomic performance. Given this high degree of economic uncertainty, the South African tomato producer’s greatest responsibility was to attempt to maintain a continuous supply of a suitable quantity and quality of produce. Given the cost constraints faced by the South African tomato producer, the importance of the tomato yield to the economic success of the farming enterprise is undeniable. These economic drivers of the tomato cost of production and retail prices are likely to recur in the SADC region as regional economic growth continues to gain momentum in the next decade.

This study highlighted the complex interaction between the impact of economics, agronomy and the ecosystem. Tomato production is likely to intensify as production costs increase and prices remain fairly high. The ecological impact of synthetic pest- and disease-control programs increase as producers attempt to challenge cultivation windows to meet their economic requirements. Further intensification through protected cultivation strategies will reduce the negative impact of climate and above-ground insect pests, but persistent monoculture will increase the burden on the soil resource in the long run. However, the ecosystem impact would have been reduced had it not been necessary to pursue above-average yield targets. However, would the commercial producer be satisfied with an 'ecologically sustainable yield'? Humphries (1993) warned against supra-commercialized unsustainable food production because the desire for profit would drive production at the expense of old-fashioned 'traditional', or sustainable, production systems centred on the basic local food supply. Indeed, in the large-scale commercial production environment, marketing and sales decisions dominate agronomic and ecological considerations (Thompson and Wilson, 1996). Thus, a continued conflict of interest between the economic and ecological aspects demanded from sustainable agriculture seems inevitable.

Conclusions

This paper focussed on the economic aspects of sustainable tomato production in the South African context. The lessons learned by these tomato producers may apply to potential tomato producers in the SADC region and beyond. It highlights the fact that sustainable agriculture is crop specific, as methods that work in one crop context may not be applicable in another. However, when talking about sustainable agriculture, especially sustainable tomato production, sooner or later we have to talk about yield. This case study demonstrates that it is critical to understand the agronomic factors that limit and promote tomato yield; however, what is agronomically possible may not be economically feasible. Furthermore, given the importance of tomato quality on gross income, and economic sustainability *per se,* it is necessary to understand the factors that influence the tomato quality profile within a planting event. The development of sustainable yet intensive production systems must continue while solutions to the economic drivers of unsustainability are pursued.

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