THE PROSPECT OF DEVELOPING SESAME INDUSTRY IN NORTHERN AUSTRALIA THROUGH ANALYSING MARKET OPPORTUNITY

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ABSTRACT: Sesame is an ancient oilseed crop mainly grown in tropical and subtropical regions. Historically, most sesame production was concentrated to tropical and sub-tropical Asian countries**,** but recently the production has been shifting from Asia to African countries because of increasing global demand. There is a further possibility of shifting the production in Northern Australia because of land availability and favourable climatic conditions. Australia imports 90 per cent of sesame consumed. There is potential for import substitution and development of export markets by producing sesame in the vast tropical and

subtropical regions of Northern Australia. This paper aims to identify the prospect of developing a sesame industry in Northern Australia by analysing global supply and demand and market opportunities. This research utilised a mixed methodology consisting of a quantitative analysis of global demand prediction and a critical review of literature and information to identify potential market opportunities. This study predicted that global production of sesame would be increased by 67 per cent by the year 2040, while the demand could double over the same period leading to a higher price for sesame. This study identified sesame as a high-value crop compared to the crops that are currently grown in Northern Australia. In addition, Northern Australia is close to international markets and has the capability of commercial-scale production and processing of sesame due to the access to suitable land and availability of genetically adapted and drought-tolerant crops for rainfed production. The regional economy of Northern Australia would be better off by commercial production of sesame considering high global demand and high international market price.

KEYWORDS: Sesame; high value crop, market opportunity analysis; regional Australia, rural economic development.

ACKNOWLEDGEMENTS: The research project was funded jointly by Cooperative Research Centre for Developing Northern Australia (CRCNA), AgriVentis Technologies Ltd and CQUniversity Australia.

1. INTRODUCTION

Sesame (*Sesamum indicum L.*) is one of the most ancient oilseed crops, which was originated in India (Bedigian, 2015). Sesame is cultivated mostly in tropical and subtropical regions, ideally within the 25^{o} north and south latitudes (Terefe *et al*., 2012). According to Food and Agriculture Organization (FAO) (2019), the world production of sesame exceeded 5.5 million tonnes in 2017, of which about 57% was produced in Africa and 40% in Asia. Mordor Intelligence (2019) estimated the global market value of sesame was about US$ 6.5 billion in 2018. It is projected that the global sesame seed market will be valued at US$17.77 billion by 2025 (Cision, 2019). Both demand and price have been increasing over the years because of changes in consumption patterns and consumers' health awareness (Mordor Intelligence, 2019). Sesame is a good source of plant protein and healthy fats and can act as an alternative to animal proteins and animal fats in human diets. Sesame is also a good source of vitamins, minerals, and fibre (Elleuch *et al.*, 2011; Zebib *et al.*, 2015). Food innovations which develop new products, such as sesame milk and ready to use *Tahina* (also known as *Tahini*), a dip made from toasted sesame, have contributed to the

growing demand for sesame seeds. In addition, sesame demand is also being driven for its use as an ingredient in pharmaceutical products, such as antioxidant tablets.

Sesame is a high-value oilseed crop with the world market price in 2018 was US$1,229/t, and the price is even higher some countries like USA with an average price of US$2,000/t in the same year. In a recent study, it was revealed the return of investment could be as high as 207.65% (Musa *et al.*, 2019). Several market studies indicated that there will be a huge gap in global sesame demand and supply in the coming years, and potentially the gap would be 3 million tonnes by 2040 (Envision intelligence, 2018; Mordor Intelligence, 2019; Hexa Research, 2018). This opens up the opportunity for the new entrants in the global sesame market and Australia, particularly Northern Australia, is one of the potential candidates.

Small and medium-scale farmers in Australia have been experiencing the impact of climate change, extreme weather impacts over production of low-value crops and domestic market saturation, higher production cost with low-profit margin (Hughes *et al.*, 2019; Akbar *et al.*, 2019; Hughes *et al.*, 2017; Newsome, 2020) resulting in landholders existing the industry or facing mental health issues (Ellis and Albrecht, 2017, Newsome, 2020). In 2018, there were about 85,000 agribusinesses across Australia, which was 3% lower than the previous year (Australian Bureau of Statistics, 2020). Therefore, diversification of high-value crops is essential, and sesame is one of the potential high-value crops in Australia. Some countries have started changing rural land use towards high-value cropping in order to boost rural economic development as well as to increase export potential (Birthal *et al.*, 2013; Asfaw *et al.*, 2010; Quisumbing *et al.*, 2015; McCullough *et al.*, 2008). Northern Australia is situated in tropical and sub-tropical climatic zones that can provide a favourable environment for sesame production (Terefe *et al.*, 2012). However, little or no information and estimation about global supply and demand for sesame is available. Existing literature on sesame primarily focuses on market size. In addition, sesame production in Australia is now in the experimental phase, and therefore, potential growers need global production and market information to de-risking their investment. This paper aims to identify the prospect of developing sesame industry in Northern Australia by exploring several factors including forecasted global demand, market trend, production capability, market share and overall market opportunity.

Following this introduction in section 1, section 2 describes the characteristics of sesame seed, world production of sesame and the study region; section 3 describes the methods and materials of the study; section

4 presents a literature review on market opportunity analysis. The findings of the study are presented in section 5 and section 6 outlines discussion and recommendations. Section 7 concludes the paper and provides the issues for future study.

2. CONCEPTUAL FRAMEWORK FOR MARKET ANALYSIS

The market analysis includes analysis and prediction of supply, consumers' choice, market share and market segmentation analysis (Day, 1981). Market research has been utilized by businesses and producers to understand the consumer demands and preferences in the pre-launch stage of a particular product (Mooi *et al.*, 2018). Exploring market opportunities for export markets leads to market grouping, market estimation and market ranking (Sheng and Mullen, 2011). The market estimation is a quantitative approach to estimate the growth of a certain product in the targeted countries. It can be argued that the identification of the market size is the key indicator for entering an international market (Ojala and Tyrvainen, 2008). Market opportunity analysis is common across organisations and business sectors, for instance, technology sector (Gruber *et al.*, 2008), public transport sector (Mulley and Nelson, 2009), the wine industry (Torres and Kunc, 2016), and small agri-business holders (Diao and Hazell, 2004).

Deloitte (2013) identified agribusiness as one of the five new fronts that would experience the most growth and contribute strongly to the Australian economy. Additionally, Australian natural resources provide the highest degree of competitive advantage for different sectors, including the agri-food sector (Deloitte, 2013). Developing new rural industries requires evidence-based strategic and operational decisions and good quality information is very useful in this process. To establish an agricultural product industry, potential investors or farmers need to know about the current and future market size (Rural Industries Research and Development Corporation (RIRDC), 2009). Moreover, a new crop industry needs to consider the information and research on location, technology, the role of government and effective business strategies (RIRDC, 2009). Therefore, market opportunity analysis for a new crop at a regional or a country level, such as sesame production in Northern Australia, requires three-dimensional analysis: global and domestic supply and demand analysis, demand trend for sesame, competitor analysis, land availability, biophysical suitability analysis, and market share analysis (Figure 1).

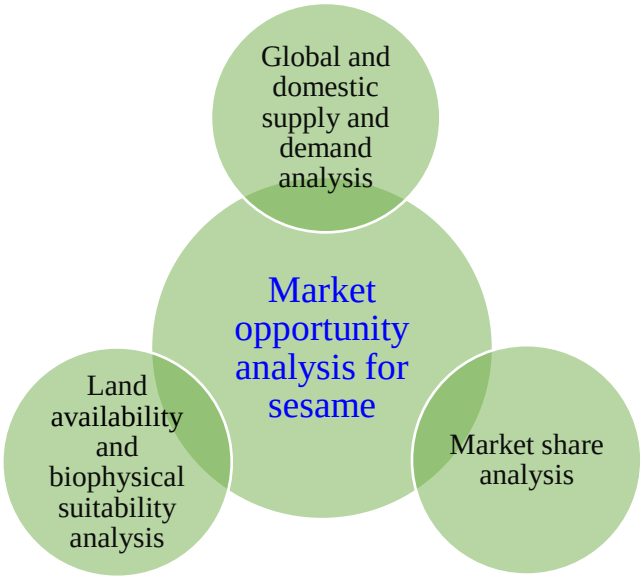

Figure 1. Conceptual Framework for Market Analysis. Source: the Authors.

In addition to the three primary factors, some other factors such as export opportunity, government to government and business to government relationship, trade war, natural or human-led disasters are also affecting the production possibilities and domestic and international market. However, these factors have not been explained in detail in this study, while the study concentrated on three primary components of market opportunity analysis (Figure 1).

3. BACKGROUND STUDY: CHARACTERISTICS OF SESAME, WORLD PRODUCTION AND THE STUDY AREA

Sesame Characteristics

The sesame plant is usually 60 to 180 cm tall, and the fruit is a dehiscent capsule, which shatters when ripe to release small seeds. The core of the seed is protected by a hull, which may be white, brown, or black, depending on the variety (Terefe *et al.*, 2012). Sesame is commonly categorised into two main market segments based on the seed coat colour, being white sesame and black sesame.

The level of dehiscence is a key trait for sesame varieties as limiting harvest loss is crucial for marketable yield. Achieving this will require breeding of new non-dehiscent varieties, optimisation of harvesting equipment, and tactical agronomic techniques such as the use of pod sealants and crop desiccants to manage harvest to control seed loss from capsules.

The sesame seed contains a 45-55% oil, which is generally higher than other oilseeds (e.g., canola seed yields 44% oil), and proteins including amino acids (Eskandari *et al.*, 2015; Pathak *et al.*, 2014). The international standard of oil content is 52%, 48%, and 45% for first, second and third grades of sesame, respectively which is generally higher than other oil seed such as canola seed yield 44% oil (Abebe, 2016; Barthet, 2016). The allowable moisture content for all grades of sesame is 6-8% (Abebe, 2016).

Geography and Climate for Sesame Cultivation

Sesame is a drought-tolerant summer crop but grows best in regions with an average annual rainfall of 625-1100mm (Terefe *et. al.*, 2012). It requires frost-free nights, with daytime temperatures around 25-27°C providing the best growth conditions. For maximum yield, the sesame plant requires a temperature range from 25^{o}C to 37^{o}C throughout the growing season. The minimum temperature required for sesame germination is 15.9°C (Langham, 2007). Sesame flowering and capsule set can be affected if temperatures drop below 10^{o}C during these developmental stages. A medium textured, fertile soil is most suitable for growth of sesame plants (Terefe *et. al.*, 2012). Sesame is very susceptible to water logging (Langham, 2007). The water requirement in the initial 30 days after sowing is very low and high rainfall during this period can impact the growth of sesame plant significantly (Langham, 2008). A well-drained soil provides a favourable root environment of sesame growth.

Global Sesame Production and Sesame Producing Regions

According to FAO (2019), in 2017, sesame was produced on 9.9 million hectares of land with an average yield of 554kg/ha. There has been an upward trend in world sesame production over the period from 2001 to 2014 (FAO, 2019). Despite the growth in supply, the price trend has tracked a similar upward path till 2014 (Figure 2).

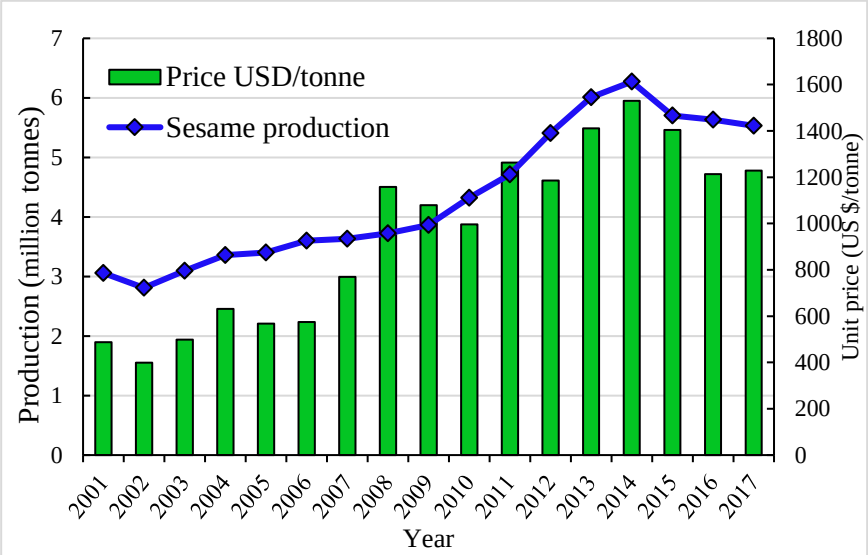

Figure 2. Global Production and Price Trends of Sesame from 2001 to 2017. Source: FAO (2019); United Nations (UN) (2019).

The trend of sesame production till 2014 indicated that the supply could not meet the demand, and hence, the price was increasing beyond the inflation rate (Figure 2). In 2014, world production of sesame and global market price reached their highest levels (Figure 2). During the war break out in Syria in 2011, the production and consumption of sesame in the Middle East declined, which is evident in the world sesame production curve after 2014 (Figure 2). Due to the reduced demand, the international market price was also decreased during the same period.

Myanmar and India were the two largest sesame producers in Asia between 2008 to 2017 (FAO, 2019). In Africa, a government initiative to support the adoption of technological interventions, including improved crop agronomy and post-harvest practices such as cleaning, grading and packaging, has resulted in significant growth in sesame production in Tanzania. Tanzania, Myanmar, and India contributed about 42% of world sesame production in 2017 (FAO, 2019).

Six leading sesame producing countries and their production over ten years are presented in Figure 3. Sesame production suffered a declining trend worldwide after 2014 (Figure 3), possibly because of the Middle East crisis. Like most of the other countries, China experienced a steady

decrease in sesame production since 2014, and they increased the volume of sesame import to meet demand.

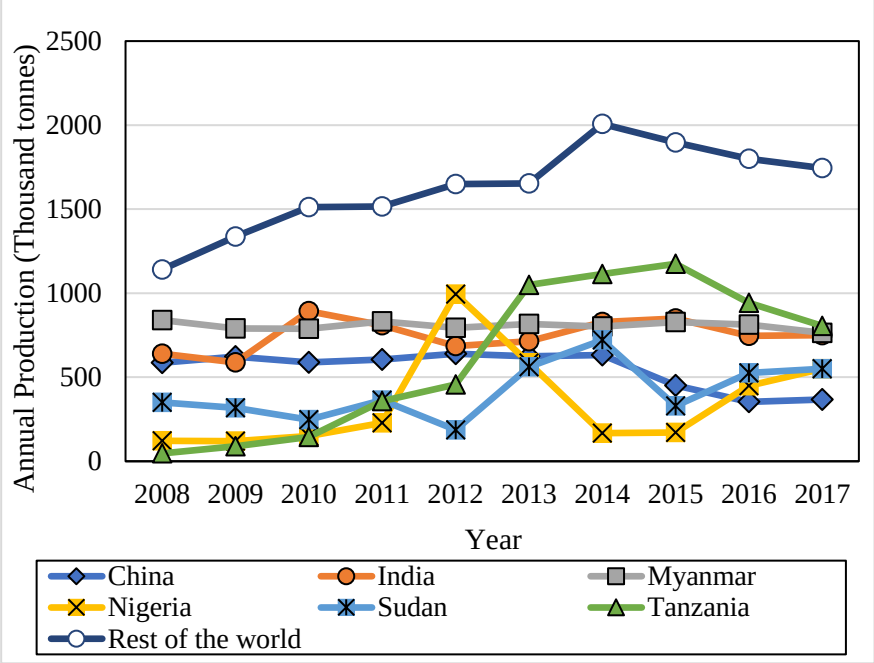

Figure 3. Global Sesame Production Trends in Different Countries (2008-2017). Source: FAO (2019).

The combined annual production and yield data provide a good indicator for the performance of the countries producing sesame over a longer-term scale. The FAO (2019) data indicate that the average yield of sesame is 550kg/ha. The average yield (kg/ha) varies considerably among the top ten sesame producing countries (Figure 4). China has the highest yield, a little over 1400kg/ha, among the leading sesame producing countries. Tanzania has achieved an increased yield in recent years, which has led to an increase in total production.

There is a large variation in yield data, and caution needs to be taken when reporting the yield data as it may be based on the harvest of trial plots or presented as a country average. There is a gap between the research yield and average yields recorded in larger-scale farming, with research yields tending to be greater; however, overall, the greater yields indicate the genetic potential of the crop. Segmenting the global production data for

white versus black sesame volumes has not been possible due to an absence of data on this trait in production statistics. Despite such a gap in yield information, production has been shifting from Asia to African countries, and this is perhaps mainly due to the land and labour availability and increasing scale of production.

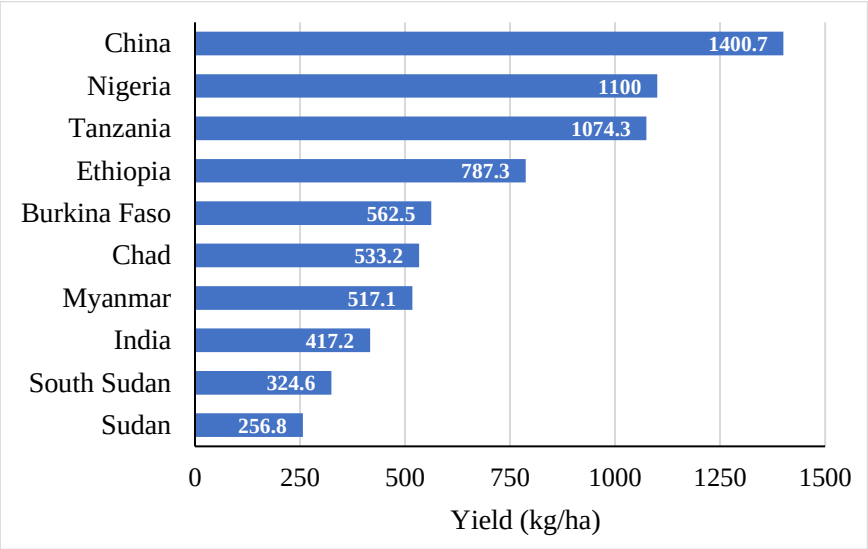

Figure 4. Sesame Yield (kg/ha) for the Top Ten Sesame Producing Countries. Source: FAO (2019).

Study Area: Northern Australia

Northern Australia as a region is roughly defined by the boundary provided by the Department of Industry, Science, Energy and Resources (DISER, 2019) in Figure 5. When accounting for only the area above the Tropic of Capricorn, the region covers approximately 40% of the total land in Australia (Commonwealth of Australia, 2015).

Northern Australia has been identified as a new planning and development region for agriculture (Commonwealth Scientific and Industrial Research Organisation, 2019). It includes the entire Northern Territory and northern parts of Queensland and Western Australia. There are three types of climatic zones in Northern Australia based on temperature and humidity: hot humid summers in the northernmost region; warm humid summers on the eastern coast; and hot dry summers in the

western and central parts of Australia (Figure 5). Broadacre cropping is currently practiced in parts of Northern Australia because of its tropical and subtropical climates, and these environments are similar to those suited to sesame production. There are five major drainage basins in Northern Australia, providing water resources (BOM, 2013), which can also support sesame farming.

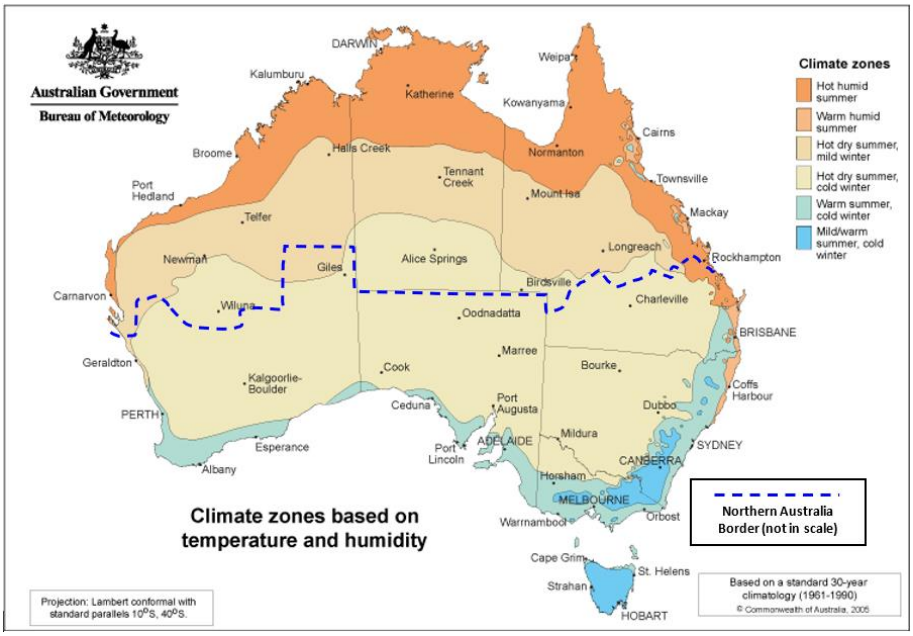

Figure 5. Climatic Zones of Australia based on Temperature and Humidity. Sources: Bureau of Meteorology (BOM) (2016); DISER (2019).

4. METHODS AND MATERIALS

This research utilised a mixed methodology consisting of quantitative trend analysis and forecasting and a critical review of literature and information to identify the market opportunities. Market opportunity analysis is a process used to identify the nature of opportunity in the form of external, internal, and financial categories (Stevens *et al.*, 2012). Among the external factors, the key elements are market size, competition, and government regulation, while the resources and objectives are the main internal factors. The financial factors cover the cost estimation and return on investment. This study mostly focuses on external factors influencing

market size and analysis of competitors or market share in the international market. The current market size was determined from available secondary data and the future trend estimation.

Secondary data have been collected from credible sources, including Food and Agricultural Organisation (FAO), World Trade Organisation (WTO), United Nations ComTrade (UN, 2019) and World Bank (2019) databases. The researchers generally use four basic methods for market size assessment, which are the analogy method, trade audits, chain ratio method and cross-sectional regression analysis (Kotabe *et al.*, 2014). However, a combination of trade audit and multiple regression are used in this study to predict the demand. Trade audits use trade data to identify the potential demand for a product or the market size for a country (Kotabe *et al.*, 2014).

Demand/market size = local production + imports – exports

The regression analysis is a statistical approach to determine the market size using a set of predictor variables. Multiple regression is one of the most common and widely used techniques for forecasting and trend analysis. In recent years, researchers have used this method for predicting rice production (Dhakal, 2018), grain production (Li *et al.*, 2015), tea production (Sitienei *et al.*, 2017) and global oil production (Aydin, 2015). In the current study, we have used both trade audits and multiple regression analysis to estimate the future demand for sesame globally and in targeted markets. Commonly used predictor variables are population, per-capita income, the proportion of high-value consumers and purchasing trends. In the mathematical form, the demand can be expressed as:

$$Market\ size = C_0 + \sum_{i=1}^{n} A_i X_i + \varepsilon_0$$

Where, C_0 is the intercepts constant, Ai are the coefficients for a regression model, X_i are the predictor variables and ε_0 is the error term. In the regression analysis, per capita gross domestic product (GDP) and purchasing power parity (PPP), population and time were used as independent variables to predict demand for sesame. However, in case of paucity of data from a single source, we used average volume derived from different sources. In the regression analysis, we considered 28 years between 1990 and 2017, available in secondary sources. Figure 6 represents the analytical approach adopted in this study.

This study also used a desktop review of the internal factors, including the natural resources and trading environment for the potential

international market. Finally, a SWOT analysis was conducted to provide direction for future study.

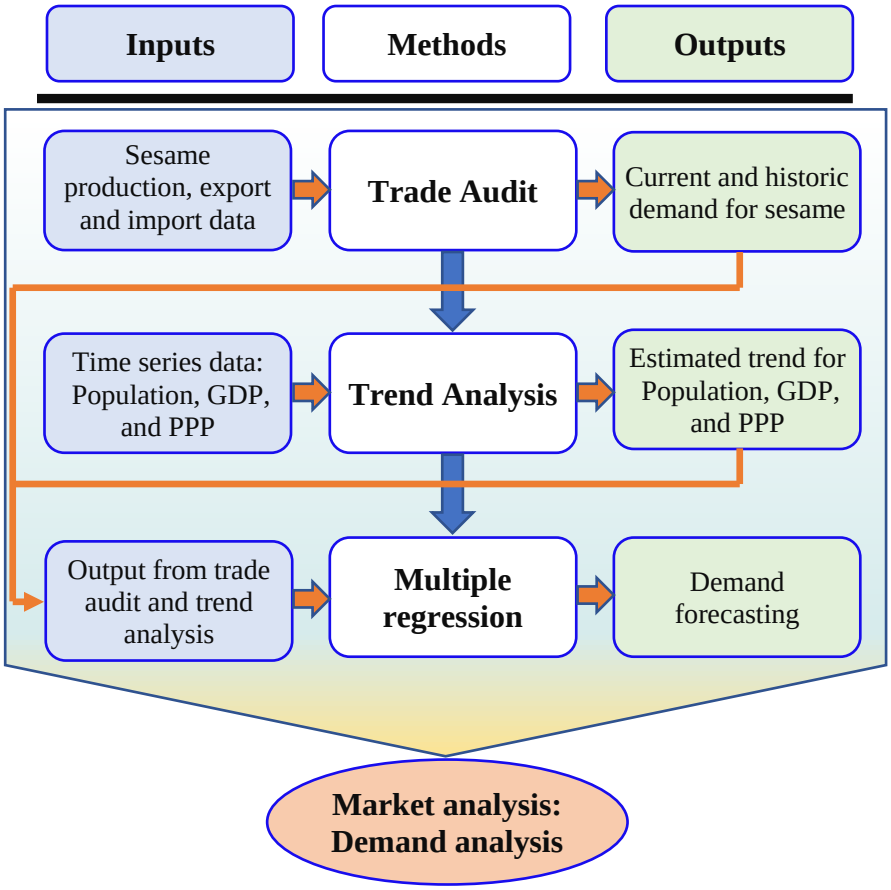

Figure 6. Analytical Approach for Estimating Demand for Sesame. Source: the Authors.

5. FINDINGS AND ANALYSIS

Global Production and Demand Analysis for Sesame

World sesame production exhibited increasing growth consistent to the growing demand (Figure 7). The analytical approach presented in Figure 6 is used to predict the forecasted global production of sesame. The dependent variables for the production forecasting are the population, per

capita gross regional product (GRP), purchasing power parity (PPP) and time, while the dependent variable is the production of sesame. Predicted results are illustrated in Figure 7 with the R^2 value for the multiple regression analysis. The summary output for the multiple regression is provided in Table 1.

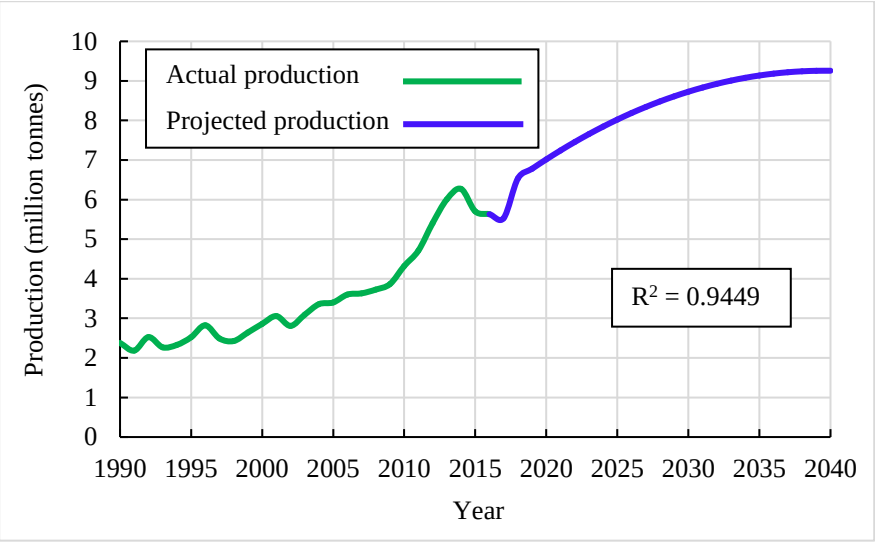

Figure 7. Projected Global Sesame Production up to 2040. Source: Authors' calculations.

The projected results suggested that the production of sesame will reach 9.26mt/year by the year 2040, resulting in a growth of about 67% over the current production level. The R^2 value of the multiple regression is 0.9449, which indicates the strong relationship between the dependent and independent variables. The summary table indicates that the variables per capita GDP and PPP are not significant, which implies that the production will rise over time and with increasing population.

Some studies have estimated the compound annual growth rate (CAGR) of demand for sesame as between 1.7% and 4.9% (Envision Intelligence, 2018; Mordor Intelligence, 2019; Hexa Research, 2018). This study considers an average CAGR of 3.3%, calculated from the published CAGR, for the future growth in global demand for sesame up to the year 2040. Therefore, global demand for sesame by 2040 will reach 12.28mt, which is about 118% of the global sesame production in 2016. This finding

reveals that there could be a potential gap of over 3mt of sesame in global demand and supply by the year 2040.

Table 1. Regression Analysis Summary Output for Global Sesame Production Trend. Source: Authors' calculations.

SUMMARY OUTPUT			
Regression Statistics			
Multiple R	0.972061014		
R Square	0.944902614		
Adjusted R Square	0.93532046		
Observations	28		
ANOVA			
	df	*F*	*Significance F*
Regression	4	98.61066871	3.95662E-14
Residual	23		
Total	27		
	Coefficients	***t Stat***	***P-value***
Intercept	2942829625	2.134092581	0.043719788
Year	-1528998.902	-2.130511631	0.044044215
Population	0.018736207	2.013483833	0.055909225
GDP Per capita	197.6458704	1.504890451	0.145962338
PPP	211.485954	1.168905349	0.254414458

Demand Analysis for Largest Export Market

Among the sesame importing countries, China holds the largest share of international trade (Figure 8). In 2016, China imported approximately 1mt of sesame from several countries, accounting for about 64% of the world's sesame imports. Japan is the second-largest sesame importer, accounting for 10% of the world's sesame imports. East Asian countries the republic of Korea and Vietnam are also among the top sesame importing countries. This indicates that Asian countries, particularly China, could be a potential export market for Australian sesame.

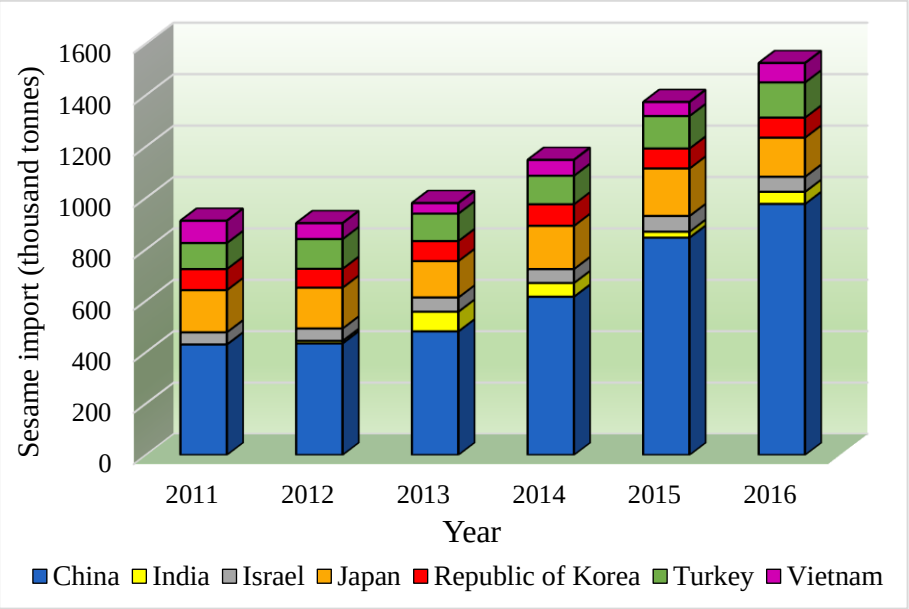

Figure 8. Import Quantity of Sesame for the Top Seven Importing Countries. Source: UN (2019).

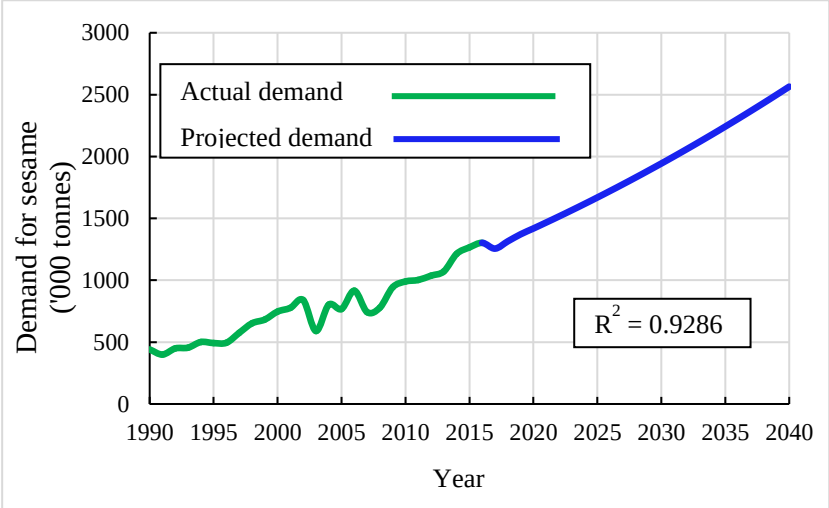

Figure 9. Projected Sesame Demand in China. Source: Authors' calculations.

The amount of sesame imported worldwide has been relatively steady over the last few years, except for China. China recorded 127% growth in sesame imports from 2011 to 2016. The future demand for sesame in China is also predicted using the same approach (Figure 6), and the results are illustrated in Figure 9.

The demand for sesame in China is predicted to reach 2.56mt by 2040 (Figure 9). The basis for this expected growth is the rapidly increasing number of middle-class families, with higher disposable incomes and changing behaviour in their food intake.

Market Share for Sesame: Export and Import

Most of the sesame producing countries in Africa export sesame outside the continent. In 2016, the global export volume of sesame reached about 1.4mt (Figure 10).

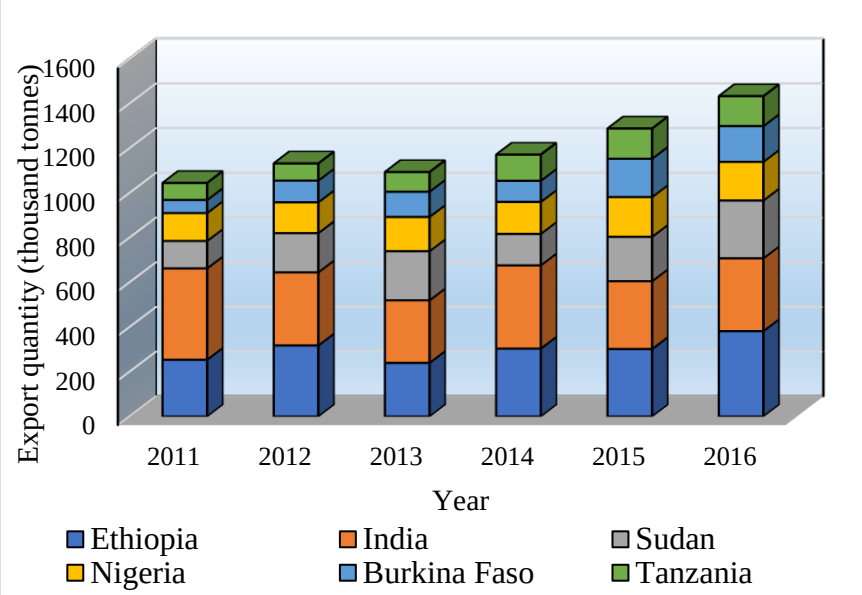

Figure 10. Export Quantity of Sesame for the Top Six Exporting Countries. Source: UN (2019).

Ethiopia and India were the two largest exporters of sesame, accounting for about 50% of global sesame exports. Over the last few years, other sesame producing African countries have exhibited steady growth in the

sesame export markets. Among the sesame exporting countries, Tanzania was the highest sesame producing country globally and the fifth largest sesame exporting country (FAO, 2019) in 2016. Over 80% of sesame produced in Tanzania was exported to China, and over 17% was exported to Japan (Table 2).

Table 2. Top Export Destinations from Tanzania. Source: FAO (2019).

Rank	Country	Export value in 2016 (USD)	Shares in export (%)
1	China	$113.55M	81.9%
2	Japan	$23.82M	17.2%
3	India	$1.06M	0.8%

Ethiopia was the top sesame exporting country in the world in 2016 with an annual export value of over US $445m. International trade data indicate that Ethiopian sesame has a stronghold in the Middle East and East Asian markets (Table 3).

Table 3. Top Export Destinations from Ethiopia. Source: FAO (2019).

Rank	Country	Export value in 2016 (USD)	Shares in export (%)
1	China	$328.57M	73.7%
2	Israel	$43.67M	9.8%
3	Turkey	$19.95M	4.5%
4	Jordan	$13.82M	3.1%
5	Republic of Korea	$9.56M	2.1%

Though China was one of the leading sesame producers with 353,000t produced in 2016, China was the leading sesame importer in the same year. This indicates a huge market demand for sesame in China. Data indicates that China imports sesame mostly from the African countries, which supplied approximately 96% of imports (Figure 11). Ethiopia supplied over 37% of sesame imported by China.

Japan also heavily relies on African countries to meet local demand. Nigeria accounted for approximately 36% of sesame imported by Japan, which is the highest among all the exporters (Figure 12). Apart from the African countries, Myanmar, Guatemala and Paraguay are among the leading sesame exporters to Japan. In 2016, the demand for sesame in

Japan was more than 152,000t. Korea produced 14,000t in 2017, and in the same year it imported 75,000t of sesame.

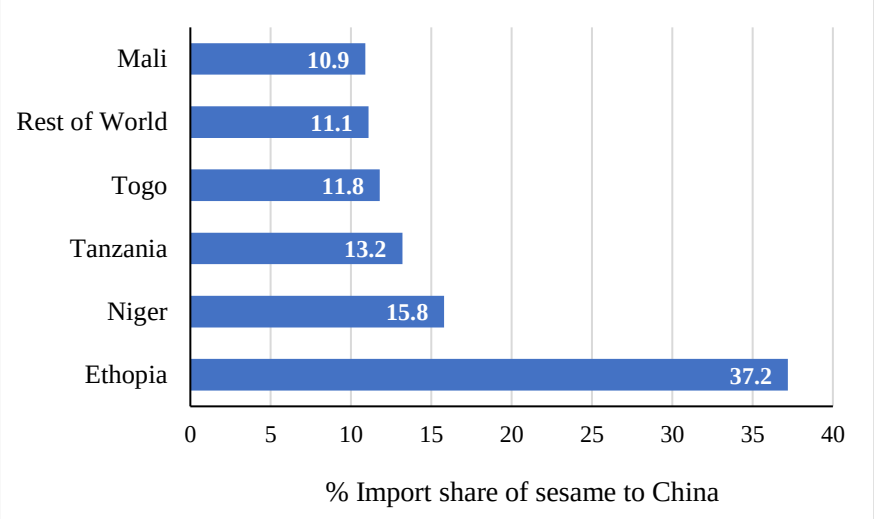

Figure 11. Market Share of Sesame Imports to China (%). Source: UN (2019).

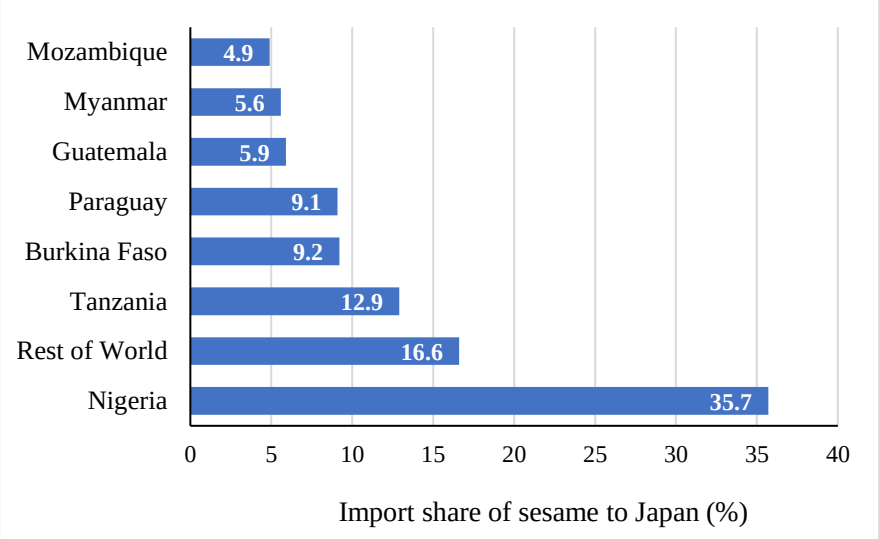

Figure 12. Market Share of Sesame Imports to Japan. Source: UN (2019).

Korea imports sesame predominantly from the two Asian countries, India and China. China, Japan and Korea are geographically close to Australia compared with other major sesame exporting countries. Australia also has existing trade agreements with these three countries.

Land Availability and Biophysical Suitability Analysis

Northern Australia is located close to the rapidly growing economic regions of Asia (Commonwealth of Australia, 2015). There is untapped potential in this region and agribusiness and food are major sectors for future growth. The basic characteristics and features of Northern Australia are highlighted in the section 3. The northernmost parts of Australia, including Darwin, Katherine, Kununurra and areas in Queensland above Cairns, possess a tropical savannah climate (Stern *et al.,* 2000). These areas experience high temperatures all year round, with distinct dry winters and wet summers. In contrast, the region along the eastern coast of Queensland from Cooktown to Ingham experiences a tropical monsoon climate. These areas receive an average of 2000mm of rainfall annually. The inland and the western part of Australia above the tropic of Capricorn has hot grassland or hot desert climate. The hot grassland climate receives more rainfall than the hot desert climate. Coastal areas of Central Queensland possess a subtropical climate with mean annual temperatures above 18^{o}C.

Plants thrive when there is an appropriate level of sunlight, heat, water, and nutrients available to them as per their nature. Sesame, as a plant, requires frost-free days to grow as well as the basic requirements in terms of sunlight, heat, water, and nutrients. Northern Australian climates do not possess frost, which is a major threat to sesame plant's growth, except for occasional incidences in inland and highlands. Furthermore, these regions have ample sunlight availability to support accumulation during the summer as well as winter months (Yeates *et al.,* 2013).

Land and soil types also influence the amount of water and nutrients that plants can extract from the soil by virtue of soil properties like water holding capacity, drainage quality, electric conductivity, cation exchange capacity, pH, etc. A recent study on soil mapping and land suitability within the catchment of Fitzroy, Darwin and Mitchell river systems suggested that there is approximately 197,000 sq km of land available for various crop production (CSIRO, 2018). However, these lands are currently being extensively used for livestock grazing. The basic soil types in Northern Australia are red loamy soils, grey loamy soils, dark reddish-

brown clay loams and stony soil (Department of Environment, Park and Water Security, 2016; Queensland Government, 2013; Schoknecht and Pathan, 2013). The loamy soils can support irrigated and occasional rainfed agriculture, and the clay soils can support both types of agriculture given enough precipitation to fill the soil profile. These types of soils are favourable for sesame production and hence provide some competitive advantages to Northern Australia.

On average, Northern Australia receives about 60% of the total rainfall in Australia, but the evaporation rate is very high due to the high temperatures in the Australian outback (Commonwealth of Australia, 2015). There is significant variability in rainfall between seasons and years, which brings additional challenges for new crop production like sesame. However, sesame is a drought-tolerant crop with an extensive root system, and it can withstand severe to moderate drought stress (Hamedani *et al.*, 2020). The Australian government has assessed three main catchments for future water harvesting projects. The catchments are Fitzroy catchment of Western Australia, Darwin catchment of Northern Territory and Mitchell catchment of Queensland (CSIRO, 2019). The literature suggests that up to 160,000 hectares of land could be cropped during the dry season in the Fitzroy catchment alone (CSIRO, 2019). The development of irrigation infrastructure within these three new catchments may provide opportunities for developing irrigated sesame production. Due to the adaptation of sesame to a hot, humid climate, there is a good opportunity to adapt sesame as either a rain-fed or a strategically irrigated crop in rotation in existing cropping systems. In general, sesame responds to additional irrigation with diminishing returns and has the best water use efficiency when water levels throughout the season are as low as 305 mm (Pereira *et al.*, 2017; Tantawy *et al.*, 2007).

Inter-regional Sesame Price

Recently, the world has experienced some fluctuation in the price of sesame seeds; however, generally prices have continued to rise despite increasing supply. The price of sesame varies based on its colour, quality (e.g. oil content), origin, moisture content and purity (admixture). According to FAO (2019), the average world price of sesame reached US$1229/t in 2018 (Figure 13). Price variation also existed in different export destinations. The international market price reveals that black sesame commands a premium of around 40-45% over white sesame. This is due to the fact that white sesame is a bulk commodity used as a food

condiment. Black sesame, which is in shorter supply, is used in higher-value markets for its oil, as a pharmaceutical ingredient, and in value-added food products. Hulled sesame seeds also have a higher price than unhulled seeds, with a price premium ranging from 10% to 15%. Raw and processed sesame arising from organic production systems attract greater premium prices in all markets (Decker and Kurnik, 2018).

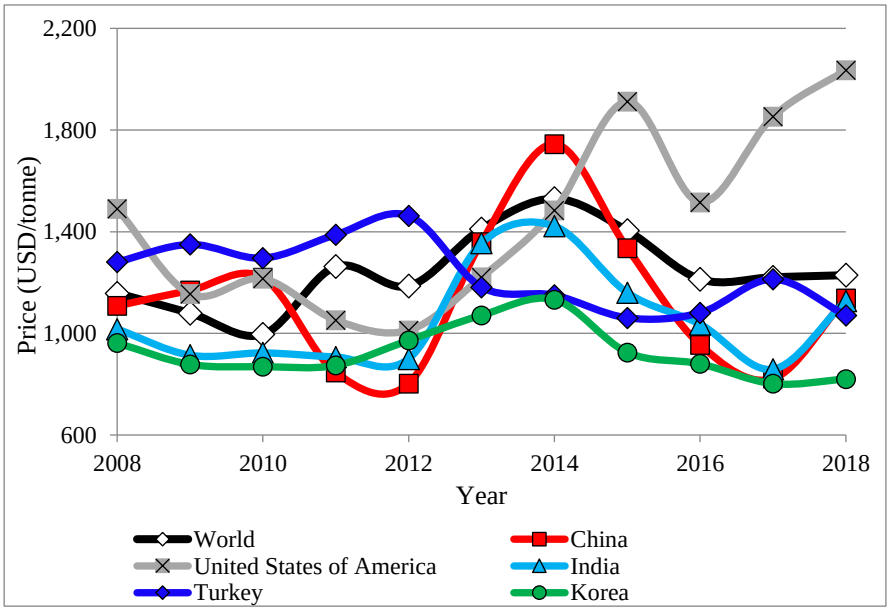

Figure 13. Price of Sesame Seeds in International Markets. Source: FAO (2019).

Market Opportunities for Australia

The current production of sesame in Australia is not listed in FAO data. However, it is estimated that approximately 525ha is currently being used to produce both white and black sesame in Australia (Bhattarai, 2019). An Israeli company, Equinom, is currently engaged in producing high-yielding white sesame in Australia (Equinom, 2020). Over the last three years, Equinom has used white sesame varieties and has implemented mechanical harvesting in field trials to obtain some preliminary data both in Queensland and New South Wales. AgriVentis Technologies Pty Ltd, an Australian-based private seed company, has invested in developing black sesame varieties and is currently producing crops in Central Queensland, primarily for seed bulking purposes to support expansion

among commercial farmers during 2020/21 summer growing season. Agronomic factors and the suitability of a range of potential production zones are also being assessed as part of a project led by CQUniversity Australia and funded by the Cooperative Research Centre for Developing Northern Australia (CRCNA) and AgriVentis Technologies Ltd, with a view to determining more precisely the likelihood and viability of establishing an Australian production base.

Australia has been importing sesame since 1966, and the demand for sesame in the domestic market has gradually increased (FAO, 2019) (Figure 14). In 2016, Australia imported about 6740t of sesame, while in the same period it exported about 60t of sesame (FAO, 2019). Data suggests that over the past 25 years, there was some fluctuation in demand. The future demand is estimated using the same method described in section 3 and the results are presented in Figure 12. However, due to the instability in demand, a short-term prediction of demand is more appropriate than a long-term prediction. The trend indicates that by 2030, the demand for sesame in the domestic market will be about 6500t.

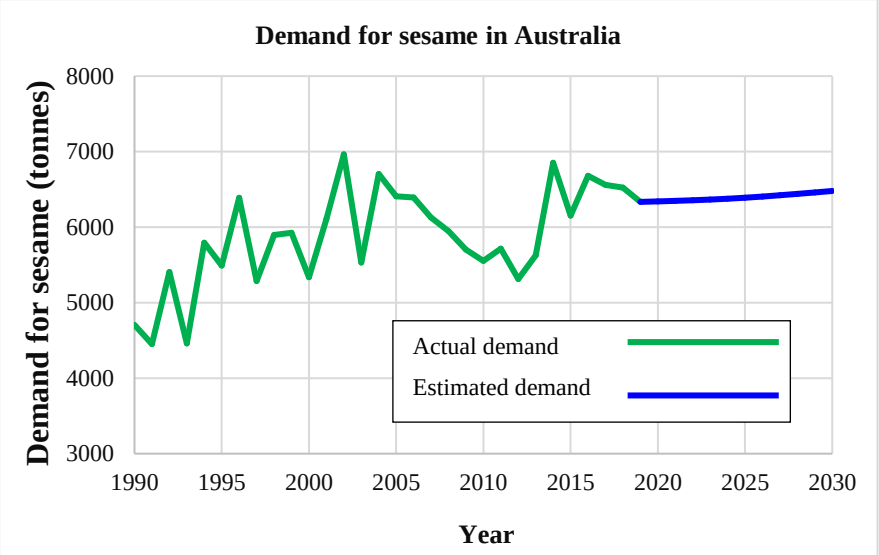

Figure 14. Projected Demand for Sesame in Australia. Source: Authors' calculations.

Establishing a sufficient local supply base that can be cost-competitive on the international market will be required if Australia is to take advantage

of geographical proximity to Asian markets over the African countries. China, Japan, the Republic of Korea, Vietnam, and other Asian demand centres for sesame are all in geographic proximity to Australia. Australia has free trade agreements with these countries as well, potentially giving Australia some additional competitive advantages. Australian farmers could also obtain a competitive advantage if they can ensure a consistent supply of high-quality sesame and leverage its perceived "clean green image" of production techniques in a product marketing promotion, as well as harness the premiums on offer such as those available for organic products.

6. DISCUSSION AND RECOMMENDATIONS

This study found a strong and growing demand for sesame since 2001 and both supply and price have increased over this period. This study predicted that the global sesame production will increase by 67% over the next 20 years, but the demand will be doubled by the same period. To meet the gap between supply and demand, some tropical and subtropical countries, including Australia can play an important role. Currently increased Asian demand for sesame, particularly demand from China, Japan and South Korea, is met by African countries such as Ethiopia, Niger, Nigeria, Togo, Mali, Tanzania, Burkina Faso and Mozambique (export market) and few Asian and Latin American countries such as Myanmar, Guatemala and Paraguay.

Sesame price varies in the international markets by geographic location, economic condition, and the quality of the produce. For example, the prices of sesame in Japanese and Korean markets are a bit higher than other Asian markets; the price of black sesame is 40-45% higher than white sesame; and raw and processed sesame arising from organic production systems attract the greater premium prices in all markets (Munyua *et al.,* 2013). Despite these, sesame oil extraction is the most common value-adding activity, and it has very high value and demand in the international market due to a long shelf-life because of the presence of antioxidants. There is an opportunity to create an international premium market where Australia can take a leading role. Currently, several trials of commercial-scale production of sesame are in progress in Northern Australia (Bhattarai, 2019). If these trials are successful, Australia could produce sesame on a large scale and replace domestic market imports as well as service export markets. However, both opportunities and barriers exist in Northern Australia (Figure 15).

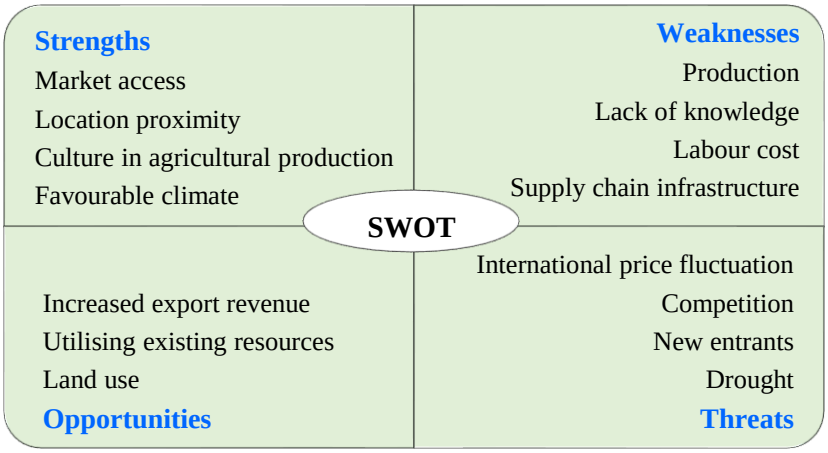

Figure 15. SWOT Analysis on Market Opportunities for the Australian Sesame Industry. Source: the Authors.

Northern Australia's land availability and favourable climate is a plus point for sesame production. Along with that, the access and proximity to the biggest export market for sesame placed Northern Australia in a strong position for developing the sesame industry. However, the lack of knowledge among the local farmers for sesame production is one major weakness. Lack of export supply chain supporting infrastructure and high labour cost are among the other barriers. The key opportunity of developing the sesame industry in Northern Australia is ensuring the economic wellbeing of small and medium scale farmers by utilizing available land and natural resources for sesame production and by increasing economic profit with a high-value crop like sesame. Price fluctuation in the international sesame market is a threat to potential sesame producers in Northern Australia. They also have to face high competition in the export market with existing sesame suppliers.

Northern Australia has a strong potential for the expansion of agriculture and several agricultural commodities that have market access to the Asian countries, including China, Japan, Republic of Korea, and Vietnam (ABARES, 2020), which are also leading sesame-consuming countries. The geographic proximity of Australia to the Asian markets gives competitive advantages over the African sesame-producing countries. Availability of land and natural resources and favourable climate offers Northern Australia an excellent opportunity to develop a sesame industry (Bennett, 2004) and increase export revenue by targeting the Asian sesame

market. However, the production of sesame in Northern Australia could be disrupted due to the lack of knowledge regarding the production and processing of sesame and high labour costs. Decker and Kurnik (2018) suggested that the sesame production system in Northern Australia needs to consider the potential threat from the competitors and new entrants in the international market. Long-term strategic planning will also be required to establish export enabling sesame supply chain infrastructure. One of the key concerns of sesame production could be the extreme weather events in Northern Australia. Though the new varieties of sesame are drought-tolerant, to date, no empirical evidence is available on the impact of Australian drought on sesame production.

7. CONCLUSION

Both sesame seed production and consumer demand have increased around the world since 2001. The demand for sesame is predicted to increase due to changing food consumption behaviour, the availability of value-added products, such as oil, pharmaceuticals and niche foods, and by-products such as sesame meal. Australia has great potential to enter into the commercial production of sesame for both domestic and export markets. Sesame is tolerant to some unfavourable weather conditions and has the potential to integrate into the existing farming systems to achieve higher-yields and high-quality value-added products. However, an initiative needs to be taken by industries to reach existing domestic markets and for a smooth expansion to international marketplaces for export. The development of sesame industry in Northern Australia will allow the local producers to diversify their production to a high-value crop, which might ensure their economic wellbeing and sustainability of their farm.

This report is based on a desktop study, and there are some limitations due to the unavailability and inconsistency of data. Further research will be required to complement this study:

- Investigation on the varietal performance and environmental suitability of the sesame crop in Northern Australia;
- A detailed value chain analysis to investigate factors including the supply chain logistics (e.g. storage, segregation, transport, etc.), product processing infrastructure and the viability of value-added products; and
- A detailed study on consumer choices on domestic and international demand for sesame seeds and its value-added products to precisely understand the current gaps in demand and projected future demand.

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