

Article

Do Sustainability Standards Exclude Small Farms? Modelling the Kenyan Floricultural Sector

Roberto Calisti ^{1,*}  and Ellen Alexandra Holtmaat ²
¹ Department of Agricultural, Food and Environmental Sciences, University of Perugia, Borgo XX Giugno, 74, 06123 Perugia, Italy

² Department of International Relations, London School of Economics, London WC2A 2AE, UK; E.A.Holtmaat@lse.ac.uk

* Correspondence: saacr@libero.it; Tel.: +39-075-812645

Abstract: This study simultaneously addresses two issues: (a) defining what counts as ‘small farms’ in the rose sector, taking the geographical and socioeconomic context into account and (b) whether the requests for certification form barriers for small farms. We focus on small farms, as they are of fundamental importance for social and economic development and significantly contribute to the environmental sustainability of agriculture and land use. An agent-based model is used for analyzing an agricultural production and supply chain. The model identifies the minimum farm size needed to cover increased costs due to sustainability certifications. The model is applied to the case study of rose production in Kenya. Kenya is one of the world’s leading flower producers. Almost all Kenya’s floricultural production is exported, and the export of stem roses accounts for about 80% by weight of Kenya’s floricultural exports. Environmental and social sustainability certification is increasingly required for farms, especially those in developing countries that want to export their products. Our findings suggest that sustainability standards disadvantage small Kenyan rose farms and constitute a further obstacle to their entry into the international rose market. In this specific context, standards limit market access for farms smaller than 4 hectares. The agent-based model proposed in this study can be adjusted to help determine the definition of ‘small farms’ in need of extra support in other sectors.

Keywords: Kenya; floriculture; small farms; sustainability standards; certification; agent-based model



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1. Introduction

Export markets increasingly require environmental and social sustainability certificates for farms, especially those in developing countries. Two topics have given rise to a long and articulated debate regarding how to define ‘small farms’ and whether the requests for certification form barriers for small farms. Excluding small farms is particularly problematic as larger farms are more often foreign owned and small farms more often locally owned. Several studies have pointed out the need to use diverse approaches to define small farms, as the contexts in which farms operate vary [1,2]. This study proposes an agent-based model (ABM) to define what should count as a ‘small farm’, taking into consideration the geographical and socio-economic context and applies this method to Kenyan rose farms.

The production of cut flowers in Kenya represents one of the main sources of income for the agricultural sector and the second main source of foreign currency after tea. Almost all floricultural production is exported; Kenya is the largest exporter of flowers to the EU, supplying about 38% of the flowers imported into the EU, mainly through the Dutch and UK markets [3]. The export of stem roses from Kenya accounts for about 80% by weight of Kenya’s floricultural exports [4].

The Kenyan floricultural sector employs, directly or indirectly, at least 600,000 people, who do not always receive an adequate wage or have the necessary job guarantees. Often

their employment is precarious [3]. Rose cultivation has a considerable environmental impact, due to its high consumption and pollution of water, especially from Lake Naivasha, around which most of the rose farms are concentrated [3]. Sustainability standards address these issues, requiring the farms to provide specific guarantees for workers and to adhere to more sustainable production processes.

The Dutch flower auctions historically play an important role in the flower trade. Traditionally, the Dutch, and later on international farmers, united themselves in the flower auction, i.e., a place where the flowers were brought to and auctioned off with a downward ticking clock. The flowers are sold to the highest bidder [5,6]. The share of the flower trade going via auctions has decreased over the past decades, and with supermarkets establishing direct relationships with farms, the importance of sustainability standards has increased. In addition, as compared with auction trade, direct trade with supermarkets require inter alia constant supply and quality, which are often more difficult for smaller farms to guarantee [7–9].

In Kenya, there are very few small farms that cultivate roses; as a matter of fact, the production is almost completely in the hands of intermediate to large farms [10,11]. Considering not only roses, but all types of flowers, there are an estimated 5000 flower farms, many of them small scale, as three quarters of the exports come from about twenty-five larger farms [10,12]. Smaller farms often grow summer flowers, used as fillers in bouquets. These flowers are mainly sold via the auction or, if directly, to florists or garden centers; markets where private standards are not required [3], and different from intermediate roses which are often sold in supermarkets. Also, Fairtrade bouquets are allowed up to 50% non-certified flowers and fillers [3]. The aim of this study is to understand if the introduction of sustainability standards is a further cause of the lack of small farms in the rose sector, along with other technical and economic factors.

Other technical and economic factors that could lead to the exclusion of small farms is the perishable nature of roses. This means that it is almost impossible to write complete contracts between buyers and suppliers [13]. As a result, trust and communication are important in the trade relationship ([13] interviews). This increases transaction costs, and therefore makes working with many small suppliers costly for supermarkets (interviews). In addition, rose production is capital intensive, due to the need for greenhouses and the costly rose varieties. Therefore, growing roses is not something everyone can start on a small scale.

As certification mainly plays a role in the European supermarket value chain, which generally demands intermediate size roses (interviews), this study excludes large-headed roses, which are usually sold via an auction and end up in florist shops and are often not certified due to lack of demand for certification ([10,14] interviews).

Export markets increasingly require environmental and social sustainability certification for farms, especially those in developing countries. Two topics have given rise to a long and articulated debate, i.e., whether requests for certification form barriers for small farms and the definition of a 'small farm'. Several studies have pointed out the need to use diverse approaches to define small farms, as the contexts in which farms operate are diverse [1,2].

1.1. Small Farms in Kenya

Karfakis et al. [15] analyzed, in detail, the efficiency of some of the most important production factors for small Kenyan farms. They noted that these were more likely to be inefficient especially with regard to labor (low productivity). Their analysis showed that farm productivity was promoted by policies that reduce transaction costs and barriers to the market, access to financial resources, and improvement of the quality of human capital. However, their study also showed the need for an approach that encourages general economic development to increase employment opportunities in other sectors and reduce over-employment in agriculture.

Several authors have defined a ‘small farm’ in the Kenyan floricultural sector by focusing on the size of land under production [3,16,17]. Mitullah et al. [17] considered that farms with an area dedicated to floriculture of less than 5 hectares were ‘small scale producers’; these farms had a “low input system with little investment” and used “mostly family labor” [17]. It needs to be mentioned that roses are a ‘high-value’ crop [18]. Meaning that much more income is generated per hectare than crops that are not ‘high-value’, such as maize and sorghum.

1.2. Definition and Importance of Small Farms

The appropriate definition of a ‘small farm’ has been the subject of discussion. A great variety of situations that impact what should count as a ‘small farm’ exist even in relatively homogeneous areas; the variety increases significantly on a continental or worldwide basis [2]. Three ways of defining farm size are: a physical definition based on the area under production; an economic definition, which considers the gross marketable production (standard gross margin); and a labor definition, which considers the number of work units conducted on a farm [1].

Given the significant difference in profitability per hectare that exists among different crops and different farms, the economic parameter could best represent the size of a farm, for example, in the USA, a farm is called a ‘small farm’ or ‘small family farm’ when it has a gross cash farm income (GCFI) of less than 250,000 USD [19]. More complex approaches attempt to define small farms by considering a plurality of physical, economic, and technical parameters [2]. However, when referring to a single production context, as in this study, the area-based definition (usually expressed in hectares) is adequate.

Lodwer et al. [20] estimated that small farms with an area of up to 2 hectares were the most prevalent farm type in the world and that, in low-income and lower-middle-income countries, small farms operate about 30–40% of the land. Rapsomanikis [21] estimated that two billion people “live in about 475 million small farm households, working on land plots smaller than 2 hectares”.

The literature discusses the productive efficiency of small farms, their effective capacity to influence the global food supply, and the most appropriate policies to support them. Holden and Binswanger [22] conducted an analysis of the relationship between small farms and the market and how factors such as transaction costs, missing economies of scale, and lack of information affect market access. These factors can limit the production efficiency and can have negative environmental effects, due to the production intensification in easily degradable environments. Since these effects can be the result of misplaced rural development and support policies, the authors concluded that these policies should be based on a careful analysis of the local situation to be truly effective. Kuivanen et al. [23] conducted a typological analysis of farms in a region in Ghana and identified some intervention models for each type of farm that aimed at improving their management and production. Guiomar et al. [2], in their study on small European farms, highlighted the need to define them according to their region of origin, given the differences in production and structure. This implies a rethinking of policies to support small farms, especially concerning their non-agricultural functions, taking into consideration the specific regional characteristics, rather than using a single approach for the whole EU.

Herrero et al. [24] estimated the contribution of farms of different sizes both in terms of the production of nutrients essential to human beings, and in terms of their impact on the environment. In the conclusion of their study, they stated, “Efforts to maintain production diversity as farm sizes increase seem to be necessary to maintain the production of diverse nutrients and viable, multifunctional, sustainable landscapes.” In general, small farms are considered to be of fundamental importance for the livelihoods of directly employed people, and also for several socioeconomic and environmental reasons, for example, sustainable management of agricultural activities and land, development of rural communities, and the conservation of biological diversity and landscape [1,25–27]. In this context, the United

Nations General Assembly has declared 2014 the ‘International Year of Family Farming’ and 2019–2028 the ‘Decade of Family Farming’ [28,29].

1.3. Sustainability Standards and Small Farms

In the flower sector in Kenya, four standards play an important role in the flower trade. The oldest standard is the Dutch MPS standard, set by Dutch producers, in 1994, in response to negative publicity on the use of pesticides on the farms. This standard requires producers to track their pesticide, water, and energy usages and waste treatment. The second oldest standard is the Kenyan Flower Council (KFC) standard which was initiated by six large Kenyan flower farms, in 1996, in response to negative publicity on flowers from Kenya [14–30]. This standard is a comprehensive standard with both social and environmental requirements. GlobalGAP, which stands for good agricultural practices, expanded its scope to flowers in 2003 [31]. It is set by supermarkets and focuses on safety, quality, and risk management. In 2004, Fairtrade launched its flower standard which emphasizes social aspects and was initiated by, among others, the Fairtrade label, NGOs, supermarkets, and a flower trader (interviews). Each of these standards differ in terms of cost structure, next to some of the changes in infrastructure the standards require, such as the building of stone toilet blocks and an indoor canteen; the standards also differ in terms of annual certification and audit fees (interviews, websites standard setters). The KFC standard is pro-rata to exported product, but most are to some extent regressive, i.e., they are relatively more expensive for smaller farms.

The political and social science literature mainly understands private sustainability standards as a new form of governance [32–40] and discusses their legitimacy [32–36] their different institutional forms [38], the coexistence of overlapping standards [41], and the conditions under which they come about [42]. Another strand of the literature looks at the impact of these standards. It asks questions such as ‘Who gains and who loses from these standards?’, ‘How does it impact smallholders in developing countries?’ and ‘What is the outcome legitimacy of these standards?’ [42–50]. Our research fits more within this last strand.

There are also several studies conducted specifically on standards in the flower sector, for example, studies by Riisgaard [10], Dolan [51], and Hughes [30–52]. Riisgaard focused on the impact of standards on labor movements and found that, through the increased presence of standards in the supermarket value chain as opposed to the auction value chain, direct trade with supermarkets increased the power of labor movements [10]. Dolan explored the link between morality and market, by looking at the Fairtrade flower standards in Kenya [51]. Hughes looked at the power exercised by UK retailers on the production of flowers and how flower trade could be characterized as a buyer-driven commodity chain. He also investigated the building of networks and circulation of knowledge by retailers in Kenya’s cut-flower sector [52] and the governmentality of sustainability standards [30]. To the best of our knowledge, there is no specific study done on the impact of standards on small farms in Kenya’s rose sector.

According to the extensive literature, it is more difficult for smaller farms to get certified [32,45,53–62]. Certifications increase the production costs and constitute large fixed costs, thereby, reducing market access for those without the financial means and tilting the market in favor of those who can spread the fixed costs over a larger production [7,9,61]. Those farms that have fewer resources and for whom the requirements are less suitable to their local context, therefore, have a harder time getting certified [32,53,63]. Those farms adopting certification have larger asset holdings, household wealth, access to services, labor endowment, and level of education when looking at EurepGAP adoption in Kenya [46]. Akyoo and Lazaro [64] found that organic certified farms were on average larger. Those that are not certified may be relegated to less profitable markets [65].

The difficulty of getting certified is often not because of the substantial requirements of the standard, but because of the administrative and financial costs ([14,66] interviews). This is illustrated by a quote from Kuiper and Gemählich on a Fairtrade flower farm in Kenya,

“A recently Fairtrade-certified farm spent between 3000 and 4000 EUR to acquire the certification; these costs were mainly concentrated in the audit and in setting up administrative structures, whereas the changes in the production process were negligible” [66]. This perspective was also confirmed by our own interviews with farmers. When farmers were asked about the obstacles to certification, they offered the following answers: “It are the procedures, documentation, keeping records, restrictions on chemicals that are the biggest burden.”; “Every other month an audit distracts from the work you are doing. Why should we sign up to a lower standard if we already have a higher standard? . . . We are a very small company, and we don’t have a team of people whose job it is to check on all standard requirements. On last audit we also didn’t get a 100% pass. With a dedicated person we could have realized that, but we can’t afford it. The standard is very procedural.”; “a lot of paperwork.”; “it is expensive”; “out of context requirements”; “We were with a plumber for 25 years, but then they said he is not certified. Well, he knows more about plumbing than anyone who is. He can’t speak English, he can’t write English, and all courses are in English. You jeopardize this person because of that. Eventually they agreed. But there are petty things like this to deal with, emails back and forth. Just an example.” (interviews). As such, the idyllic picture that some standards present of small scale and natural production might contrast with the reality where larger and more industrial farms are better placed to obtain the certificate [51,64,67,68].

On the one hand, standards can have positive consequences for small farms. Standards can help farmers develop skills and signal quality [50,69,70]. Signaling quality can reduce buyers’ transaction costs, thereby, facilitating sourcing from multiple suppliers, and thus potentially facilitating market access for smaller farms [43,71,72]. Small farms may also use certification to differentiate their product and derive a higher price for it. It can help them overcome insecurities that international buyers may have if public standards are lacking [73].

On the other hand, standards can have no or very little influence on small farms. Standards spread through demand for standards [74]; farmers often only consider certification once they receive the demand from existing or potential buyers (interviews). Particularly large European retailers require suppliers to be certified [9]. These retailers often control the value chain and have detailed requirements for their suppliers. As a result, the transaction costs are high and retailers prefer to work with a small number of large suppliers [9]. Small suppliers may often not be certified, simply because they are too small for the type of buyers who demand certificates [30].

In addition, the capital intensity of a sector matters. The more capital intensive a sector is, the more access to capital is required for a firm to start in this sector. This creates a high entry barrier, which may prevent the presence of farms that would be unable to afford certification [75].

2. Materials and Methods

We present a novel method to define what is considered to be a ‘small farm’ in a context in which certification is demanded. We take the market and the context in which a farm operates into account, as the notion of ‘small farm’ depends very much on the specific socioeconomic situation. This method can be used to define the minimum size of a farm to meet the certification costs. By defining the minimum size, it becomes relatively easy to identify which farms need external help, for example, to achieve certification or for other purposes.

As a novelty, this study uses an agent-based model, to which we input the information available to us on farm characteristics, the market, and the general context. We use various types of data for the setup of the model, concerning the behavior of operators, their interrelationships, and the relationship with the market in which they operate.

Existing studies addressing the impact of certification requests for sustainability standards on small producers often use a large-n statistical analysis with firm-level data [46,64,76],

are more descriptive in nature [45,53], or have dealt with this matter from a qualitative point of view [77,78].

This study diverges by using an agent-based model (ABM). An ABM can be used to model complex interactions which are much more difficult to consider using statistical models. Previously, Latynskiy and Berger [79] used an ABM to investigate the effects of certification on small coffee farms in Uganda, and found that the added value of certification was substantially lower than the price premium, because of certification costs; however, they did not address the definition of a ‘small farm’.

The advantage of an agent-based model is that it can take the interdependencies and the time sensitivity of the certification decision into account. The strongest incentive to certify probably comes from the demand of an important existing buyer (interviews). In addition, potential buyers’ demands might form an incentive (interviews). The price buyers are willing to pay, depends on the scarcity of certified products. In return, the share of certified producers likely depends again on the price for certified products. This complex dependency can be modeled with an ABM.

An ABM also provides the option to model hypothetical situations. Testing the impact of the demand for private sustainability standards in the rose sector in Kenya via a statistical model is further complicated by a lack of data access. Institutions in Kenya have not been willing or able to provide a list of registered rose farms and data on export volumes and trade partners over time. Standard setters surprisingly have not been willing or able to provide an overview of certified farms over time. In addition, farms themselves do not readily provide their trade data to researchers, *inter alia* to keep it secret to competitors. Moreover, it is nearly impossible to track down this information for farms that no longer exist. The agent-based model generates this data if the underlying micro-mechanisms are correctly specified.

An ABM is also useful in modeling feedback loops. Agents’ behaviors depend on the behavior of other agents, who’s behavior also depends on the behavior of other agents. This creates reinforcing effects because the interaction between the agents creates the macro-level outcome, and the macro-level outcome influences the agents. All these features of ABM are particularly useful in the agricultural supply chain [80–82].

To the best of our knowledge, fewer studies have looked at the certification of sustainability standards in the floricultural sector than in other agricultural production sectors. This study started from field research, based on our interviews with Kenyan operators, which allowed us to understand their behavior and to determine a series of parameters that, together with the literature data and the few official statistical data available, were the basis for the definition of the model.

2.1. Model Implementation

Different sources of data were used in this study. The first source concerned interviews with farmers, retailers, traders, and standard setters. This helped to understand how agents interacted and what their interests and strategies were. To this end, we spoke with 40 Kenyan farmers, visited 30 farms, did interviews with several traders, retailers, a representative from the auctions, and representatives of standard setting organizations.

The interviews with flower farmers were conducted in the summer of 2016, on flower farms in Kenya, mainly around Lake Naivasha, Nakuru, and Nairobi. As some owners had multiple farms, 43 farms were covered with these 30 interviews. In addition, ten interviews were done with farmers at a trade fair in Aalsmeer, The Netherlands, in 2017. An impression of the different rose farms in Kenya was obtained via desk research, lists of certified farms, a list of farms obtained from a breeder, sector magazines, and via other farmers. By selecting the farms for an interview, attention was paid to diversifying the sample in terms of size, location, altitude, and ownership. After those criteria were considered, mainly practical limitations determined the selection. For example, it was easier to include farms in regions with many flower farms and relatively close to Naivasha; therefore, no farms from Mount Kenya were included. The sample was further limited

by being able to reach farmers via phone or getting a response via mail, within the three weeks we had available. This likely led to an overrepresentation of well-organized farms in our sample. Most farmers we were able to reach via phone agreed to be interviewed.

The interviews were semi-structured to obtain both factual information as well as perceptions. We had a list of about hundred questions. The questions addressed both the present situation and the situation since the start of the farms. On the one hand we collected data points, such as the age of a farm, the size of a farm, when did the farm get certified and to what standards, the cost of certification, and how were these standards financed. On the other hand, we wanted to hear about the farmers experience with the standards, what made them decide to get certified, and what were potential obstacles. We also asked about their trading relationships. The interviews often lasted around two hours. Most interviews were recorded and the information from the interviews was put into spreadsheet software.

Next to farmers, ten participants in the global value chain, twelve people connected to the standard setters, and five experts on the flower sector were interviewed. The global value chain participants consisted of a variety of traders and supermarkets and the people connected to standard setters were those working for the four main standards in the Kenyan flower sector, MPS, KFC, Fairtrade, and GlobalGAP, or who were involved in initiating the standards.

As for the number of farms, buyers, their sizes, the costs of certification, ties with buyers, etc., we used the data collected during the interviews and via desk research. We also used data from Macchiavello and Morjaria [13] who were able to obtain the data from Kenya's Horticultural Crops Directorate and were so kind to share it with us. Some other data were taken from the literature [3,5,15–17].

The model was built in NetLogo 6.0.4. [83]. It reproduces the dynamics of the Kenyan floricultural market, which is strongly influenced by the international market since almost all of its production is aimed at exporting. The model simulates the interactions between the main players in this market, through the formation of more or less temporary connections, which determine the quantities of roses sold, the fixing of prices, and the adherence to certification standards.

Two main agents are defined in the model: farms producing roses and buyers who buy these roses through supply agreements. The auction market represents a third agent, to which the farms turn when they have no contact with buyers or when they have surpluses not covered by the agreements with the buyers.

Roses are traded in different markets [10]. In general, large-headed roses are sold by florists and intermediate roses are sold by retailers. Florists often buy their roses via an auction. Retailers receive more pressure to implement standards than florists, and therefore this pressure for standards is particularly felt by farms growing intermediate-sized roses. At the same time, retailers more often buy their roses via direct connections with farms; therefore, the demand on the auction for intermediate roses is lower and the price often worse (interviews). Therefore, the large-headed and intermediate rose markets can be seen as two different markets. The model focuses on the intermediate roses market. In this study, we excluded large-headed roses, which are mainly sold via an auction and end up in florist shops and are often not certified due to lack of demand for certification (interviews).

The model works on a weekly basis, i.e., the time passes in discrete steps ('ticks' in the NetLogo terminology) each representing one week. According to the data provided by the Kenyan Horticultural Crops Directorate and further processed by us, in 2018, about 100 million roses per week were exported on average; we chose to consider half of this volume in the model, that is, 50 million roses per week, which according to our estimates could be the quantity actually marketed by the number of farms (100) considered in the model. We assumed 100 farms sufficient for the model, without making it too heavy. This number of roses is considered in the setup phase of the model which is subject to variation during the model operation; through a stochastic function, changes to the demand can be introduced, both positive and negative; these changes represent the variations that

normally occur in the real demand. In addition, the production can undergo variations for many reasons (e.g., in Macchiavello and Morjaria [13]) and the model considers this possibility through another stochastic function.

Each buyer connects at random with some farms, asking for roses to buy and trying to fix a supply agreement. The agreement is possible when the farm has sufficient production to cover the buyer's request and has the certification(s) required by the buyer. If a farm does not have the required certification it can decide to obtain a certification, especially when it has a significant number of certification requests. Once an agreement has been established between the farm and the buyer, it remains valid indefinitely, until changed market conditions impose its redefinition (interviews). Figure 1 shows the model operating scheme. In the Supplementary Materials, we provide an in-depth model description following the ODD (overview, design concepts, details) protocol for describing agent-based models.

2.1.1. The Buyers

Following the data by Macchiavello and Morjaria [13], in the model, 71 buyers are defined. In the real floricultural market, the characteristics of buyers are quite diverse [3]; in the model, for simplicity, the buyers differ on the four characteristics described below.

Quantity of roses requested by each buyer. In the setup phase, the average number of roses requested per week by each buyer was about 0.7 million roses, with a minimum of about 0.27 million and a maximum of 1.81 million; in the model, as in reality, there is a small number of buyers who have much higher purchasing capacity than the others. During the model operation, the quantities varied according to market trends.

Certification requested by the buyer. The model, through a random function, sets the number and type of certifications each buyer requests. The model considers four standards that are very common in the Kenyan market: MPS, KFC, GlobalGAP, and Fairtrade. Each buyer can request from zero to four certifications. This is a predetermined characteristic during the setup phase and does not change during the operation of the model. This reflects the real situation, where normally each buyer has relationships with a defined set of retailers and requires roses with constant quality. The model does not investigate the differences between the four certifications and the consequences on farms and buyers; it just investigates the relationship between the number of certifications attempted or possessed by the farms and their performance. Therefore, the model distinguishes the four standards exclusively on the basis of certification fees, without considering other characteristics.

Table 1 shows the distribution ranges of buyers among the various certifications and the quantities of roses they require. The ranges are quite wide since the distribution of the certifications requested by the buyers is the result of a large estimate, based on the interviews and on the limited data available on the websites of the certification bodies; therefore, it was preferred that, in the model, these values varied from one repetition to another, to cover a wide range of values.

Each buyer defines a price per rose (willingness to pay) which considers both the average farms' production costs and the scarcity of roses with the required certifications. This mechanism means that in the very early stages of the model's operation, the prices offered for certified roses are quite high because certified farms are absent or few.

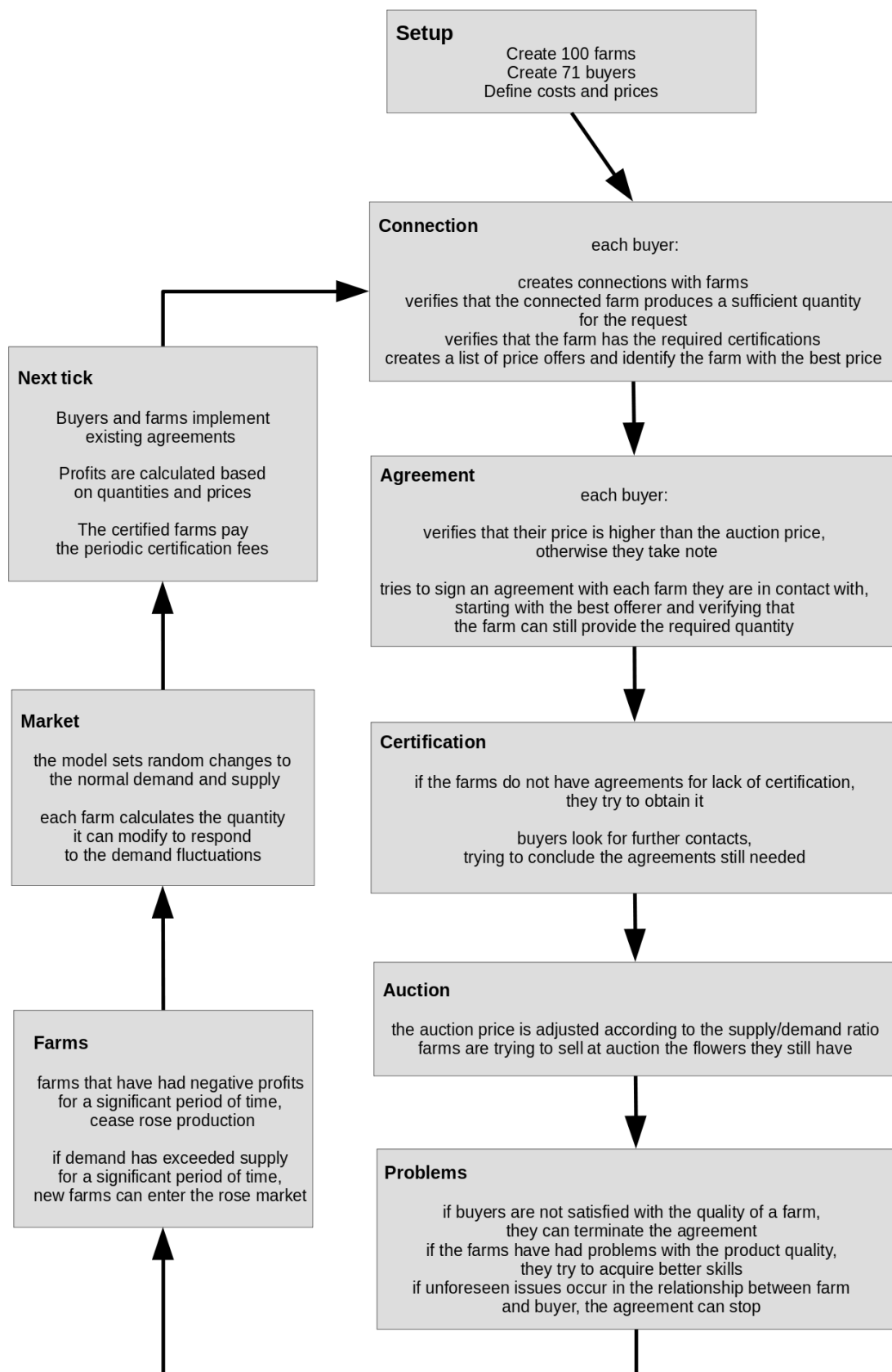


Figure 1. Model operating scheme.

Table 1. Certifications, number of buyers, and number of requested roses. Minimum and maximum in 50 model repetitions.

Type or No. of Certifications	No. of Model Buyers	No. of Roses Requested by Buyers (Millions)
MPS	14–27	5.8–22.4
KFC	10–17	5.1–20.0
GlobalGAP	16–18	6.0–18.3
Fairtrade	12–24	6.5–21.0
No certification	20–27	6.9–18.9
1 certification	25–33	
2 certifications	8–21	31.1–43.1
3 certifications	1–4	
4 certifications	0–2	

In the model, each buyer has a preferred maximum number of suppliers. Transaction costs are the costs involved in establishing a trade, for example, the search costs, the communication costs, or the risks of a transaction. The transaction costs in rose trade are relatively high, particularly, because of the characteristics of trading a natural product, which makes contracts per definition incomplete [13], and therefore most buyers prefer to keep the number of suppliers low. Standards reduce uncertainty and provide information, thereby lowering transaction costs and increasing the number of suppliers a buyer wants to work with. If buyers can work with more suppliers, then small suppliers are no longer excluded by large buyers. Macchiavello and Morjaria [13] found an average number of suppliers per buyer equal to 2.66, to be considered stable over 10 weeks; the model considered an average number a little higher, equal to almost 4 suppliers per buyer, to also take into account possible sporadic suppliers.

2.1.2. The Farms

In the model setup, 100 farms are defined. Forty of these farms represent the current Kenyan farms that cultivate stem roses; 15 farms are medium-size farms, with 5 to 20 hectares of greenhouses; and 25 farms are large size farms, with 20 to 110 hectares of greenhouses. The other 60 farms are small (less than 5 hectares), representative of small Kenyan farms that grow flowers in general. Currently, there are very few small farms that grow roses in Kenya; as a hypothesis, the model assumes that all these 60 farms have already started the production of roses and that they fully interact with buyers and the auction market. Therefore, the model allows for understanding the behavior of small farms and the difficulties they have in the real market. In the 50 repetitions of the model, the average size of the farms that existed during the operation of the model was 16.67 ha, the minimum size of farm was 0.76 ha, and the maximum size of farm 106.03 ha. Figure 2 shows the distribution of the farms in relation to the cultivated area.

New farms can be created during the model operation, when, for at least two years, the demand for roses significantly exceeds the production capacity of existing farms; therefore, there is a good chance that new farms will be opened to meet the increased demand.

A farm ceases rose production when, for at least two years, it makes significant negative profits from this production; this is more likely to happen when demand is decreasing, and the farms' production capacity significantly exceeds demand.

Each farm has a given annual production of stem roses, which is calculated based on the cultivated area and an average production of 1.53 million roses per hectare per year. This average production was calculated from the data collected in the interviews. In reality, the average production per hectare has a fair variability depending on the cultivated varieties and the type of management. In the model, the same unitary production is used for all the farms, so that the trend of certifications is not influenced by this variability. At the model setup, the rose production is set equal to the demand, i.e., 50 million roses per week; during the operation of the model, the quantities vary as described above. Farms

can modify the quantity of produced roses within certain limits, to respond to demand changes, thanks to some agronomic practices, as in reality [84].

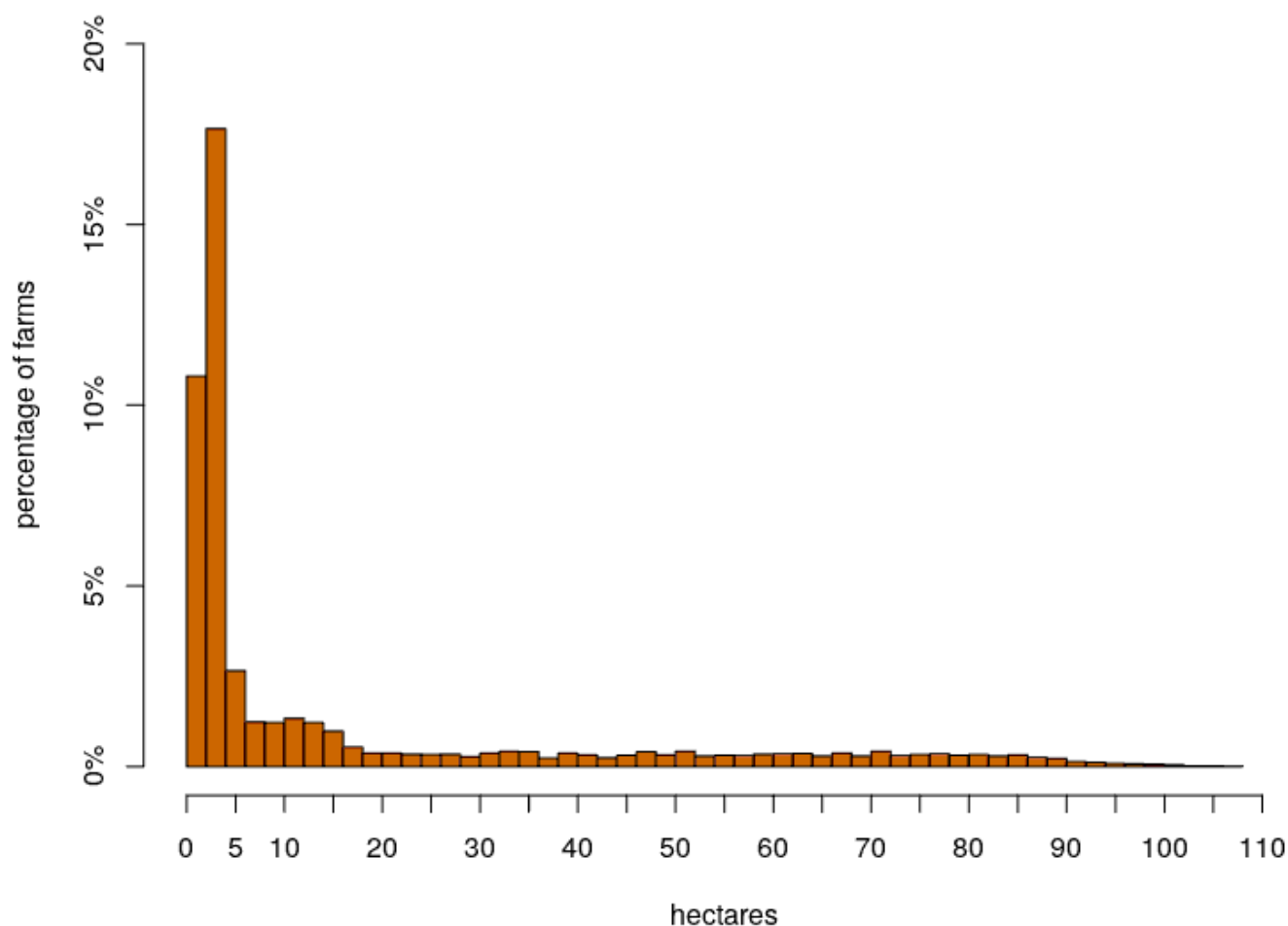


Figure 2. Frequency distribution of the cultivated area of roses per farm.

No farm is certified at setup. Farms can adhere distinctly to one or more of the four standards when a buyer requests certification. The farm assesses the immediate costs of certification and, if it has sufficient financial capacity, undertakes certification. The model calculates the certification fee based on empirical formulas that simulate the real calculation made by the certification bodies; the real calculation is indeed somewhat obscure in some cases since some certification bodies do not communicate exactly the calculation mechanism. However, with a series of simulations based on what is reported on various websites, it was possible to calculate the approximate fees. The fees are slightly regressive, meaning that they are disproportionately higher for smaller farms. The model assumes that the distinction between being certified or not depends mainly on the financial capacity, which is essential to pay the certification fees and the higher costs due to the requirements for certification, such as compliance with quality standards of production, ensuring contractual wages for labor, adaptation to production standards more respectful of the environment, etc.; this assumption is consistent with what is found in the literature [3] and during interviews. If the farm does not have sufficient financial capacity to undertake certification, the model takes note thanks to a counter of failed attempts at certification. Each farm may be contacted by a large number of buyers requesting one or more certifications; these contacts may be repeated many times with the same buyer, since over time market conditions may change in terms of both demand and rose production. Therefore, the number of certification requests from buyers can be very large for each non-certified farm; every time the farm

fails to undertake certification, the counter is increased, becoming one of the fundamental outputs of the model.

Each farm has its cost per stem determined by a random function within a fairly narrow range, but considering some economies of scale, i.e., as the size of the company increases, unit costs fall [15]. This cost includes all the costs incurred by the farm, both fixed and variable, which, based on the interviews, are equal to 25–26% and 74–75% of the unit cost, respectively. When the farm adheres to a standard, the costs change, as in reality.

When a farm and a buyer reach a supply agreement, the unit price is fixed with an empirical Function (1), which simulates a price negotiation based on a weighted average that considers the price proposed by the farm, the buyer's willingness to pay, and the general market trend represented by the auction average price. The latter price (*aprice*) is given a greater weight than the other two, because the general market trend strongly conditions the negotiation. The prices fixed in the agreements are a bit higher than the average auction prices (interviews):

$$sellprice = \frac{bprice + fprice + (aprice * w)}{w + 2} \quad (1)$$

where *sellprice* is the price per stem as agreed between farm and buyer, *bprice* is the buyer's price (willingness to pay), *fprice* is the unit price offered by the farm, *aprice* is the average auction price, and *w* is the weight of the average auction price.

The supply agreement between farm and buyer persists as long as market conditions remain fairly stable, giving rise to repeated trades between the two parties. This link is not a very binding contract, it is quite regularly not even in written form, as highlighted by Macchiavello and Morjaria [13] and found in our interviews. Therefore, the model provides for the renegotiation of the price at each sale and the possibility to dissolve and reform the link at any time, depending on the changed market conditions.

For each farm, the model records the 'history of profits' that it has achieved year by year. The annual profit is calculated using the empirical Formula (2), which considers the income from the roses sold as compared with the total costs incurred:

$$profit = (\sum_{i=1}^n qsold_i * sellprice_i) - (totqgrown * ucost) \quad (2)$$

where *profit* is the farm's annual profit, *qsold* is the number of roses sold in the trade *I*, *sellprice* is the unit selling price in the trade *I*, *totqgrown* is the total number of roses grown in a year, and *ucost* is the unit production cost

Since stem rose production requires sufficient starting capital, in the model, all farms have an initial capital proportional to their size (interviews). This capital is increased or decreased each year based on positive or negative profits, and, after a few years, it is entirely made up of the sum of the annual profits. The trend of the 'history of profits' determines the possibility of the farm to continue the production of roses and the possibility of making new investments, such as those necessary for certification. In the model, a farm can decide to stop the production of roses when, after at least having been four years in production (which is about two thirds of the average duration in full production of a rose orchard), it has made losses exceeding 5% of the annual production costs in the last two years.

2.1.3. The Auction

Some farms sell their roses at an auction. This is due to two circumstances: the farm has no agreement with any buyer, or the farm has a part of production that has not been able to sell to buyers. The price on a flower auction fluctuates, but, in general, the price on the auction is considered to be lower than the buyers' prices (interviews). The average auction price is dependent on the quantities offered and is very volatile especially on a seasonal basis [5]. The model implemented a function that simulates the result of an auction, calculating an average auction price that, for simplicity, the model assigns to all roses traded in the auction market. This function is merely empirical and is the result of a

series of tests aimed at obtaining a function that gives results consistent with the average real auction prices.

2.2. Model Operation, Repetitions, and Time Frame

As reported in Section 2.1 the model, essentially, is based on literature published in the period 2014–2019 [3,5,13,15–17], on data obtained from our interviews and research carried out in the period 2016–2017, on trade data from 2004–2008 obtained from Macchiavello and Morjaria, and on the few official statistical data from 2018–2019. All these data allowed us to build a realistic model, both from the point of view of numerical quantities and from the point of view of production and market trends. From this time frame, the model develops a series of simulations of future market trends, simulations that are based on trends, both normal and exceptional fluctuations, that actually happened in recent years and, therefore, possible in the future as well.

We run two different versions of the model, which we compare: in the first version, the real market is simulated, in which buyers request the four certificates; in the second version, we simulate a hypothetical market in which buyers do not require any certification. All the other environmental and agent characteristics are identical in both versions. From here on, the two versions are simply identified as ‘with’ and ‘without’ certification. For each of the two ways, the functioning of the model is replicated 50 times, to collect an adequate set of data. In each repetition, the model is made to proceed for 1664 weeks (ticks), equal to 32 years. The first two years (that is the first 104 ticks) are used for the model setup; in this phase, the first connections among the operators are established, so that, in the following years, the model starts from a base of knowledge among the operators already consolidated in a network, and therefore, from the third year, the model enters the full operation where many changes are possible.

3. Results and Discussion

The model randomly simulates stable, increasing, or decreasing market trends, so as to generate variable trends in the produced and marketed quantities, and in prices.

Referencing to the produced, demanded, and sold average quantities (Table 2), there is a considerable range of variation between minimums and maximums, which is consistent both with the recurring seasonal variations that are characteristic of the flower market in general and of roses in particular [5], and with the considerable variations, especially increasing, that have occurred in the past years [3]. The total quantity marketed by the model’s farms (on average 49.4 million roses per week) was slightly lower than the production (50 million), which is consistent with what happens in reality, because there is often a share of unsold roses. The share sold directly to buyers has always been much higher than the share sold at an auction; this is consistent with the interviews since both farms and buyers prefer to deal directly.

Table 2. Quantities considered in the model and the range of variation in 50 repetitions (thousands of roses per week).

	Minimum	Mean	Maximum
Sum of average weekly production potential	28,790	49,932	81,536
Total actual weekly production	28,266	50,005	84,114
Total weekly demand from buyers	29,043	50,155	88,278
Total weekly quantity actually sold	28,266	49,392	83,588
Total weekly quantity actually sold to buyers	22,596	39,567	59,800
Total weekly quantity actually sold by auction	2176	9825	33,093

Referring to costs and unit prices, the prices in the model fluctuated in a range very close to those reported in the literature [5,13]. As happens in reality ([13], confirmed by interviews), in the model the prices fixed with a direct agreement between farm and buyer are a little higher than the average auction price. The model calculates the average unit

profit of the farms, which was 12.4% in the case of direct sales to buyers and 4.9% in the case of auctions (Table 3); there is no real evidence of this, as most of the farms interviewed were reluctant or unable to give exact profit margins. However, the few answers that we obtained from the interviews suggests that the average profit margin obtained by the model is not far from reality; some farms stated that over a decade ago it was possible to obtain profits of some 20%, but today they have considerably decreased and, in some cases, are almost zero; all this also depending on the trend of the euro/dollar exchange rate (interviews).

Table 3. Unit profits generated in the model (averages of all farms in 50 repetitions).

	Minimum	Mean	Maximum
Profits in direct trade (Euros per rose)	0.027	0.0361	0.0498
Profits on auction (Euros per rose)	−0.002	0.0141	0.0325
Profits in direct trade (percentage)	10.03%	12.44%	16.32%
Profits on auction (percentage)	−0.74%	4.86%	10.65%

3.1. Comparison of Simulations ‘with’ and ‘without’ Certification

The data in Table 4 show that the farms in the market ‘with’ certification have a significantly higher fluidity than those in the simulation ‘without’ certification. In the ‘with’ market the number of farms created by the model is much higher (17.5% more) than in the ‘without’ scenario; this is because in the ‘with’ market, the percentage of farms that are forced to stop producing roses is significantly higher, and therefore the percentage of farms that can remain in business is lower.

Table 4. Results of model operation. Comparison of ways ‘with’ and ‘without’ certification. Sum of the 50 repetitions of model running.

		‘With’ Certification	‘Without’ Certification
All the farms created by the model (of which 100 in the setup phase)	No. of farms created	9827	8363
	Size of farms created (hectares)	Min: 0.760 Mean: 11.022 Max: 106.030	Min: 0.73 Mean: 12.30 Max: 102.19
Farm still active at the end of the simulation (1664 weeks)	Number of farms	3154 (32.1%)	3300 (39.5%)
	Mean farm size (hectares)	25.94	25.82
	Mean duration (years)	16.46	19.99
	Mean profit (euros)	29,146.94	35,146.08
Farms that ceased production during the simulation	Number of farms	6673 (67.9%)	5063 (60.5%)
	Mean farm size (hectares)	3.97	3.49
	Mean duration (years)	7.93	9.23
	Mean profit (euros)	−3029.46	−2151.32

Concerning the duration in activity of the farms, there is a longer duration in the ‘without’ scenario, both for the farms that have ceased production and for those still active at the end of simulation; therefore, certification has negatively affected the ability of farms to remain on the market.

Concerning the average profits of the last two years simulation, in the ‘without’ scenario, the farms that are still active, on average, have had higher profits, while the farms that have had to stop production have had lower losses than those in the ‘with’ scenario. Again, certification has harmed profitability. Since the only difference between the two scenarios is the existence of certifications, this is likely the cause of the greater instability.

Taking into consideration the average size of the farms considered as a whole, there are no substantial differences between the two simulations; in both, the average size of the ceased farms is much smaller (about 3–4 hectares) than that of the still active farms (about

25–27 hectares). A higher percentage of farms have ceased rose production in the scenario ‘with’ certification.

Figure 3 shows the incidence of ceased farms in the two types of simulation in relation to size. In both simulations, the percentage of farms that had to stop production decreased as the size of the farm increased, but, in the simulation ‘with’ certification, the percentage of farms that had to stop production was always higher than in the simulation ‘without’. In particular, the result of farms under 3 hectares is of interest, because the difference is more uncertain and less significant. This seems to indicate that a size of fewer than 3 hectares creates other problems for the farms, in addition to those related to certification.

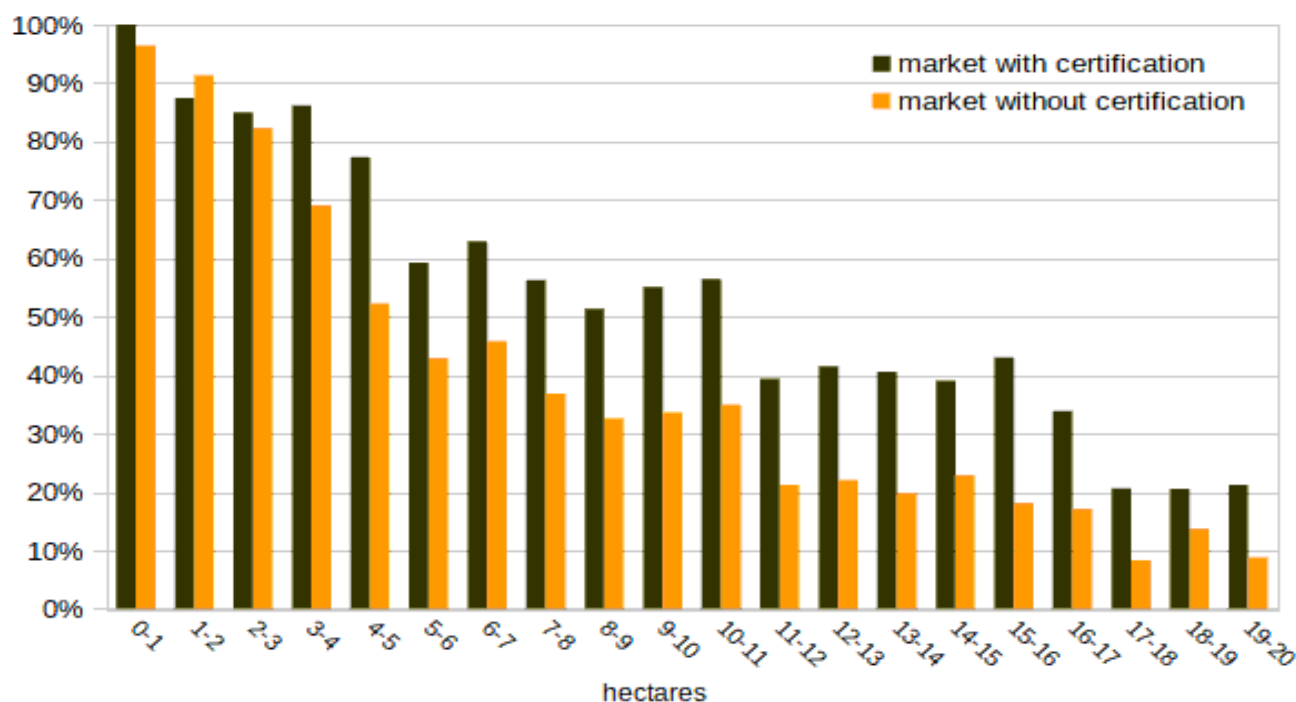


Figure 3. Incidence of ceased farms, according to their size.

3.2. Results of the Simulation ‘with’ Certification

This section analyses the overall results obtained from the 50 repetitions of the model that simulated the real market, in which most buyers require at least one certificate (interviews).

In the model, every week, each farm updates the historical series of its profits, which becomes a good index of its financial capacity, which periodically changes according to the economic trend. Therefore, a farm can continually reconsider the possibility of adhering to one or more certification standards; therefore, generating a high number of certification attempts until this is obtained or until the farm ceases production of roses.

A number of farms have never made attempts at certification, because they have never had contact with buyers who request it. The total number of these farms was significant, i.e., 1817 (18.5% of the total); the average farm size was 1.25 hectares (standard deviation of 0.36); these farms probably cannot provide the minimum quantities required by buyers.

The results regarding the farms that have been urged by buyers to undertake certification show that most of the farms were able to obtain certification (7756 farms over 8010 urged), and only a small number failed (254 attempts, equal to 3.2%). All the farms that failed to obtain certification were smaller than 3.9 hectares.

Figure 4 shows that almost all farms over 3 hectares were able to obtain certification, while the possibility of obtaining it decreased rapidly for farms below 3 hectares.

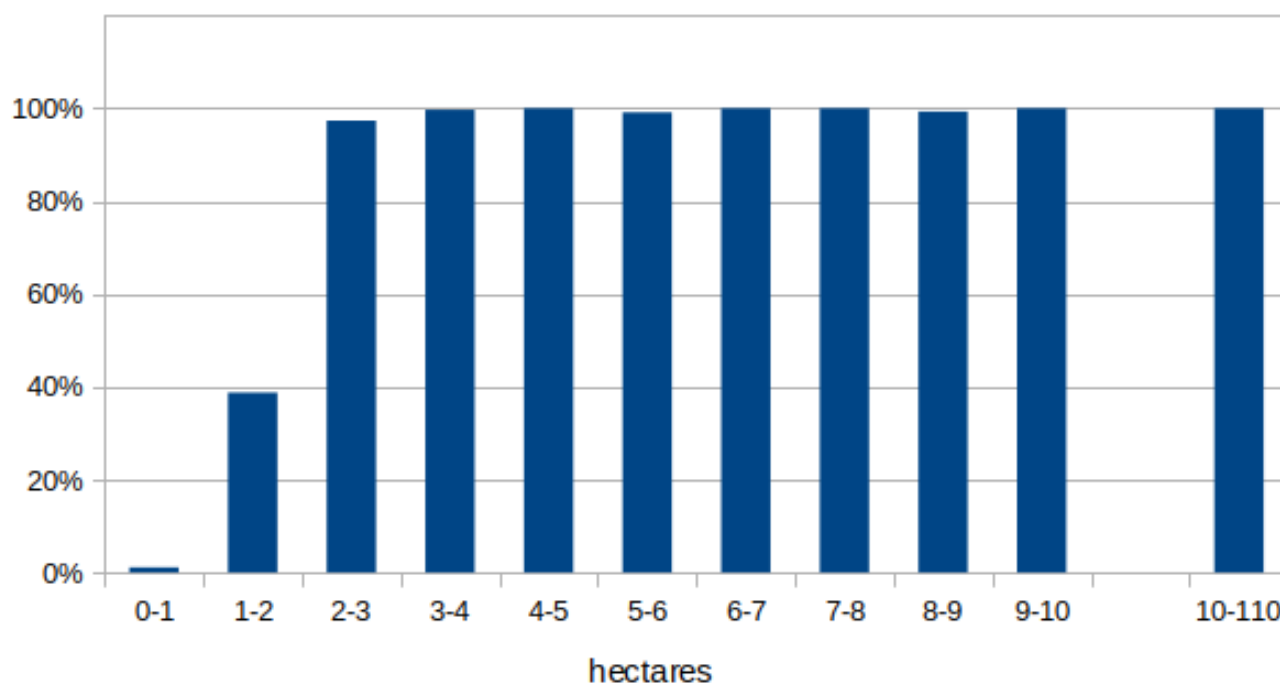


Figure 4. Incidence of farms that obtained the certification, according to their size.

Figure 5 shows the mean number of failed certification attempts, in relation to farm size. There were zero failed certification attempts for farms of at least 14 hectares. These farms have never had any problems obtaining certification. The number of failed attempts increases exponentially as the size of the farm decreases from 5 to 2 hectares. This means that the difficulties of obtaining certification increase dramatically as the size decreases, and that these farms have only been able to certify themselves when market conditions have guaranteed them sufficient financial resources, i.e., when the growing market has allowed more profitable prices. Lastly, the number of failed attempts decreases for farms under 2 hectares. These farms often do not have the minimum quantities required by buyers asking for certification, so they are less stimulated to obtain it.

Figure 6 shows the percentage incidence of certified farms that were able to continue the production of roses until the end of the simulation as compared with the total number of farms that obtained certification. The incidence of farms that were able to remain active increased sharply as the size of the farm increased: no farm active under 1 hectare, about 14% of farms below 4 hectares, 23% of farms between 4 and 5 hectares, more than 40% of farms between 5 and 10 hectares, 60% of farms between 10 and 20 hectares, and 91% of farms over 20 hectares. The lack of certification played a role, i.e., among farms below 5 hectares, only 11.4% of non-certified farms were able to remain active against about 15% of certified farms. This may indicate that the difficulty of obtaining certification aggravates an already difficult situation for small farms.

The chi-square test shows that the influence of the farm size is extremely significant ($p\text{-value} < 2.48 \times 10^{-7}$).

Data in Table 5 confirm that larger farms are more likely to remain active and also that they are more likely to obtain all four certifications.

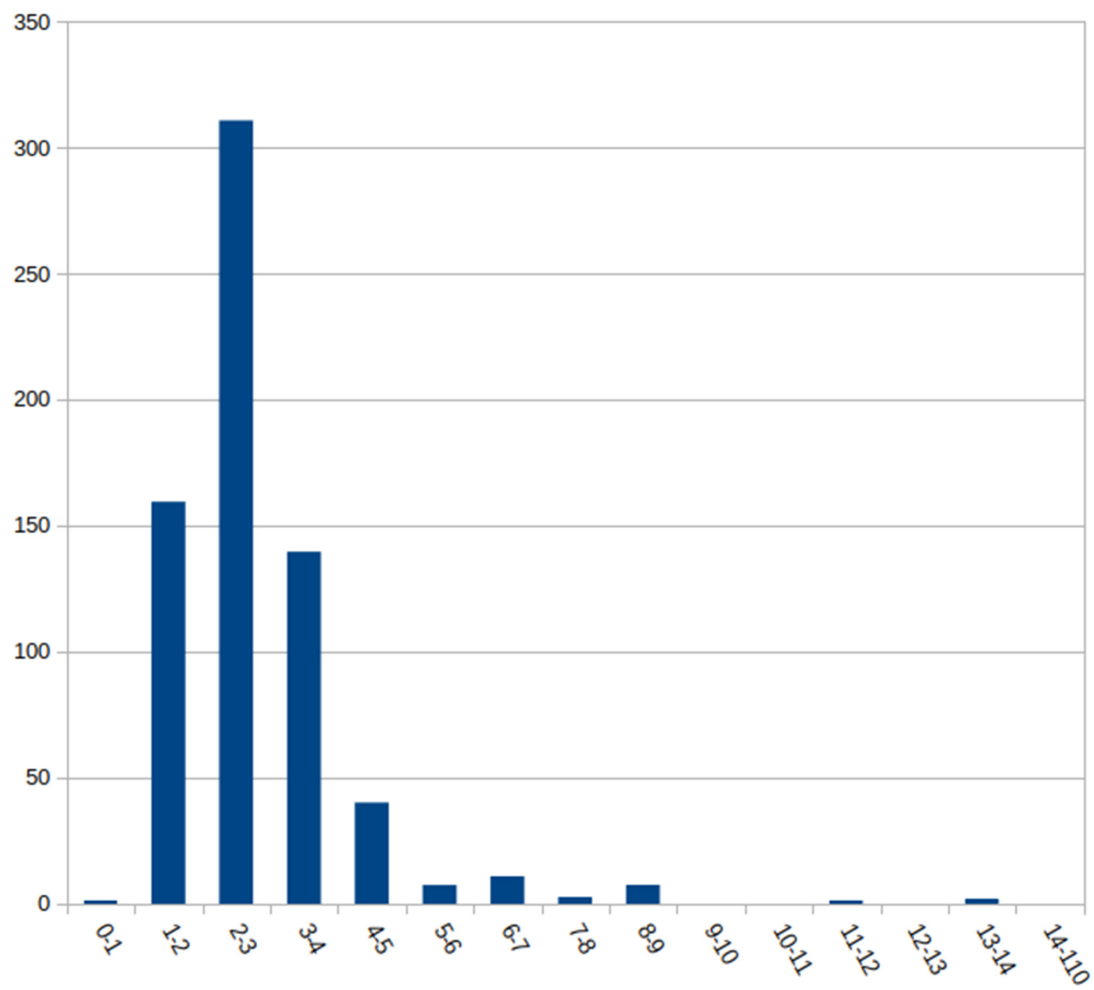


Figure 5. Mean number of failed certification attempts, in relation to the farm size in hectares.

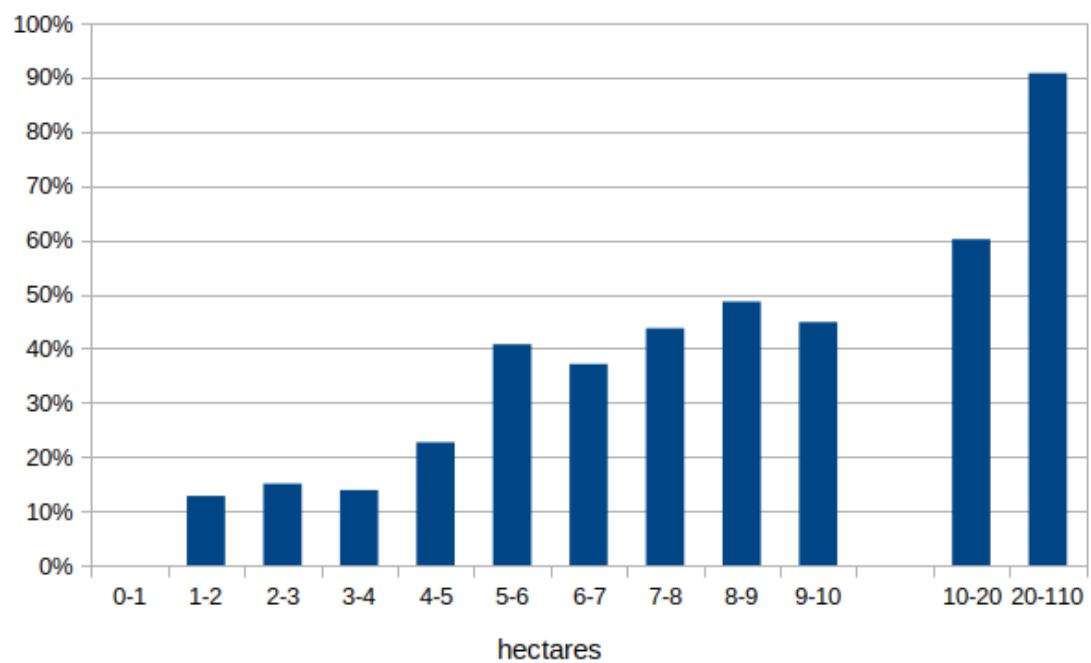


Figure 6. Incidence of certified and still active farms as compared with the total number of certified farms (active and ceased), according to their size.

Table 5. Average size of active and ceased farms, in relation to the number of certifications.

	No. of Active Farms	Average Size of Active Farms (ha)	No. of Ceased Farms	Average Size of Ceased Farms (ha)
Farms with 1–3 certifications	456	3.08	2186	2.29
Farms with 4 certifications	2389	33.47	2725	7.08

3.3. Validation

The model, in this study, was empirically validated according to the following methodology, largely based on the indications by Tesfatsion [85].

The validity of the functions, the value of internal variables, and the validity of the results of individual methods were debugged during and after the model's source code writing. These checks were carried out by making the values and results of the various internal processes explicit in the output and proceeding step-by-step in the source code debugging. Particular attention was paid to the methods of calculating the unit prices of roses and the profits of the farms, which, after many adjustments, led to the definition of Functions (1) and (2), respectively.

Another verification was carried out by simulating three constant trends of the demand for flowers: market without variations, market in constant growth, market in constant decline. Many repetitions of the three scenarios were performed and the model always behaved as expected, after the first phase of necessary adjustment. With the absence of variations, the model reached a balance between supply and demand and kept the prices, the number of farms, and their profits constant. With the constant growth in demand, flower production constantly increased in the model, through new rose plants entering into production. As a result, prices remained constant since the equilibrium between supply and demand was continuously recreated. With a constant decrease in demand, there was a progressive cessation of production, from the smallest to the largest farms, depending on the different levels of cost due to economies of scale, until the complete end of production.

The model was based on real input data (number and size of farms, production quantities, prices, etc.), so that the output originated was immediately comparable with real market data, as far as possible due to the lack of official statistics. This is also due to the close relationship that exists in this market between prices and supply and demand. As a result, the prices of the model always remained in a range very close to those reported in the literature. The extent of their fluctuations was compatible with those verified in the literature on general market shocks [13] and seasonal cycles [5]. The realistic fluctuation of prices makes the level of profitability of the model's farms and the consequent financial capacity plausible.

4. Conclusions

The developed agent-based model shows that the presence of certifications makes the stem rose production sector in Kenya more 'fluid' than a market without certifications. This fluidity means, above all, that over time a greater number of farms enter and leave the production of roses, and therefore farms have a greater probability to be forced to stop production when the market becomes more competitive. In this context, small farms are more likely to cease than medium and large farms, and the demand for certification for small farms tends to aggravate a situation that is already difficult, especially for farms smaller than 3 hectares, which are often forced to act in a marginal market.

With a detailed analysis of the results of the model that simulates the request for certification, we showed that farms under 5 hectares, and much more so under 4 hectares, have had far more difficulty in undertaking certification than medium and large farms, due to the difficulty of dealing with high costs. The model showed that most small farms can obtain certification in good market times and after many attempts, but it also showed that they are much more likely to make negative profits, and therefore have to stop production.

While 91% of certified farms above 20 hectares have been able to always remain active in the production of roses, just 14% of the farms below 4 hectares and 23% of farms between 4 and 5 hectares were able to do the same. Considering the farms that failed to obtain certification (all smaller than 3.9 hectares), the percentage of farms that remain active drops to about 11%; this small difference could mean that obtaining a certification can help small farms to survive.

According to these results, in the Kenyan rose sector, we should define a ‘small farm’ as a farm smaller than 4 hectares. However, under certain conditions, also farms between 4 and 5 hectares could be defined as small farms and might require extra attention. This study shows that the costs related to certification tends to disadvantage small farms, and therefore constitute an obstacle to their survival in the Kenyan cut rose market, but also that being certified can be important for them. Possible remedies could be the availability of public or private financial contributions to support certification and the establishment of small farms’ associations managing certification, as is already occurring in some cases in Kenya. Another remedy would be certification fees pro-rata to the value of flowers exported.

Using agent-based modeling has made it possible to accurately measure the size limits of what constitutes a small farm in a given production and trading context. Obtaining results expressed by numerical data makes the influence of farm size, market trends, and other parameters on the capacity of farms to certify production more evident. With the necessary adaptations, this method could be useful to define the size of small farms also in other specific contexts. This would help in establishing the limit for which external support becomes necessary to ensure the viability of small farms, which are, after all, by most considered to be fundamental for the livelihoods of directly employed people and important for a good socioeconomic and environmental situation.

The findings in this study have socioeconomic implications. Standards make it relatively easier to survive for larger farms. In Kenya, we see that these are generally the farms established by former European farmers, former Kenyan bankers and politicians, or Indian Kenyan businessmen (interviews). It makes it more difficult for local Kenyans with less starting capital to succeed. This increases chances of people working for foreign employers, it likely increases the political influence of the already powerful, and it reduces the bargaining power of labor which is dependent on a few large employers.

As a result, it is important to foster a network of small producers with a strong governance capacity, which enables them access to effective knowledge of market dynamics and allows the network to have bargaining power that individual farms alone could not have.

The protection and support of small farms is of fundamental importance for benefits that are more difficult to achieve with large industrial farms: maintained and increased biodiversity, varied landscape, greater adaptability and resilience to climate change, faster possibility of responding to agricultural market dynamics, and increased and diversified job and enterprise opportunities.

Supplementary Materials: The following are available online at <https://www.mdpi.com/article/10.3390/earth2040051/s1>, Model description following the ODD (overview, design concepts, details) protocol (in a separate file).

Author Contributions: This work was carried out in close collaboration between the authors. The ABM model was written together; E.A.H. carried out the field research, doing the necessary interviews and elaborating the relative data, the main bibliographic research, and wrote a part of the introduction, the literature review, and the first part of the model’s description; R.C. performed the operation of the model, collected and processed the output data and derived the results, wrote the discussion about the small farms, with the related bibliographic research, the second part of the model’s description, and the parts about the results and their discussion. The whole text was then revised together. All authors have read and agreed to the published version of the manuscript.

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Code Availability Statement: The authors reserve the right to decide on the availability of the model's source code, following a qualified request.

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