Impacts of hailstorm on urban agriculture in Northern of Maputo City and Matola (Mozambique) - An analysis in climate change perspective

Impactos da precipitação de granizo na agricultura urbana no Norte da Cidade de Maputo e Matola (Moçambique) - Uma análise na perspectiva das alterações climáticas

Bernardino Bernardo
Faculty of Earth Sciences and Environment, Universidade Pedagógica de Maputo, Mozambique
nhacundela.berna@gmail.com
https://orcid.org/0000-0003-4979-2929

Elisa Nhambire
Faculty of Earth Sciences and Environment, Universidade Pedagógica de Maputo, Mozambique
eenhambire@yahoo.com.br
http://orcid.org/0000-0003-0006-7638

Alice Freia
Department of Geosciences, University of Rovuma-Niassa
acbfreia@gmail.com
https://orcid.org/0000-0002-2619-4953

Octávio Manuel de Jesus
Faculty of Earth Sciences and Environment, Universidade Pedagógica de Maputo, Mozambique
Moçambiqueoctaviom2001@yahoo.es
https://orcid.org/0000-0001-5618-1320

José Júlio Júnior Guambe
Faculty of Earth Sciences and Environment, Universidade Pedagógica de Maputo, Mozambique
jjjguambe137@gmail.com
https://orcid.org/0000-0002-0224-1903

Zacarias Ombe
Faculty of Earth Sciences and Environment, Universidade Pedagógica de Maputo, Mozambique
zuyyaombe@hotmail.com
https://orcid.org/0000-0001-9804-7760

Gustavo Dgedge
Faculty of Earth Sciences and Environment, Universidade Pedagógica de Maputo, Mozambique
Moçambique.gudgedge@gmail.com
http://orcid.org/0000-0002-5054-8440

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Abstract

On the night of 1 June 2021, the northern region of Maputo and Matola city was buffeted by hailstorms of various sizes, the most predominant ranging from 0.5 cm - 4.5 cm. This study aims to analyze the impacts of hailstorms on urban horticulture in the northern strip of Maputo and Matola city. We also observed the effects on domestic horticultural production in some neighborhoods affected by hailstorms. Mixed methodology was chosen, supported by the following methods and techniques: bibliographical and documental research, direct observation, measurement of the dimension and characteristics of the hail generated in the soil, cartography, interview, analysis, and synthesis. In all production areas it was notorious the total and partial destruction of ready-to-cut vegetable, with emphasis on cabbage, lettuce, and onions, which resulted in heavy financial losses for farmers. These losses generated a significant increase in vegetable prices in the following days in local markets. This research suggests the need to closely monitor weather events considering the dynamics imposed by climate change, as well as to improve the system of communicating environmental risks to the most vulnerable population.

Keywords: hailstorm, horticulture, risk, damage, climate change.

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Resumo

Na noite de 1 de junho de 2021, a região norte da cidade de Maputo e Matola foi fustigada por precipitação de granizo de vários tamanhos, os mais predominantes variando entre 0,5 cm - 4,5 cm. Este estudo visa analisar os impactos da precipitação de granizo na horticultura urbana da faixa norte da cidade de Maputo e Matola. Foi escolhida uma abordagem mista, apoiada pelos seguintes métodos e técnicas: pesquisa bibliográfica e documental, observação directa, medição do tamanho de granizo e das feições geradas no solo, método cartográfico, entrevista, análise e síntese. Em todas as áreas de produção das hortícolas foi notória a destruição total e parcial de culturas prontas ao corte, com ênfase na couve, alface e cebola, o que resultou em elevadas perdas financeiras para os agricultores. Estas perdas geraram um aumento significativo dos preços das hortícolas nos dias subsequentes nos mercados locais. Esta investigação sugere a necessidade de acompanhamento minucioso dos fenómenos climáticos tendo em conta a dinâmica imposta pelas alterações climáticas, bem como melhorar o sistema de comunicação dos riscos climáticos à população mais vulnerável.

Palavras-chave: precipitação de granizo, horticultura, risco, danos, mudança climática.

1. Introduction

Agriculture is one of the activities most affected by climate change in Mozambique, especially droughts and floods (Buchir et al., 2022; Raupach et al., 2021; Recha et al., 2017; CIA, 2017). However, in recent years, new meteorological phenomena associated with climate change, including precipitation or hail fall, have affected new parts of the globe with greater intensity and in particular Mozambique, generating destructive impacts on agriculture and various economic systems in resource-poor households (Várallyay, 2010; Twena, 2006; FAO, 2021).

Hailstorm is an extreme event characterized by precipitation of water in solid state (Caldana et al., 2019; Nicolaides et al., 2008). The formation of hail occurs from atmospheric instabilities. Its occurrence is related to localized events, since the precipitation cells are limited to the incidence of Cumulonimbus type clouds (Dessens, 1986; Changon et al., 2009; Klein et al., 2011). Hail has extremely rapid solidification through sublimation, in which the passage from the gaseous state directly to the solid occurs. Its formation happens in the upper part of the cloud, where the temperature is lower, favoring the transformation of water droplets into ice particles with a diameter that can vary from 0.5 to 15 cm (Vidal et al., 2007; Caldana et al., 2019). Its main means of formation are by convective systems, instabilities caused by the passage of cold fronts or, on a larger scale, by the Meso scale Convective Complexes - MCC (Blamey et al., 2017; Capozzi et al., 2018; Laviola et al., 2020)

In geographical terms hailstorms occur more frequently in temperate zones and are not common in tropical and subtropical climates (Prein et al., 2018). However, in recent years, climate change is pointed out as the possible cause of normal changes in the rainfall distribution pattern in Mozambique (Brooks, 2013; Bal et al., 2014). Thus, worldwide data on geophysical hailfall risk areas from 1979 to 2015 were synthesized (Prein et al., 2018) (Figure 1).

In the map, the southwestern strip of Maputo province (Libombo's chain) is included in areas with probability of hailstorm for 3 days and decreases towards the northeast (Matola city and Maputo) to about 3 hours of fall for the period in analysis. Studies on hail in Mozambique associate this phenomenon to the passage of cold fronts, which come from the south polar zone, carrying cold maritime air, affecting especially the coastal regions to the south, which includes Maputo city, Maputo, Gaza and Inhambane provinces (Muchangos, 1999).

Several studies show that whenever hail fall is recorded, there are reports of economic losses, particularly in agriculture, where damage can be to vegetative structures, flower, and fruit (Finger et al., 2012; Gelcer et al., 2016). In urban areas, urban agriculture and particularly horticulture is vulnerable to weather events, where hail fall damage is one among the extreme weather events that severely affect crops in a short space of time (Nicolaides et al., 2008). The destructive effects of hail are defined by the size, intensity, and the duration of hail precipitation (Caldana et al., 2020). Several studies show that an average time of 8 to 10 minutes of hail fall is sufficient to destroy several crops estimated to be worth millions of dollars (Hohl et al., 2002; Parker et al., 2005; Nicolaides et al., 2008; Blamey et al., 2017) It is estimated that the hail fall time in northern Maputo and Matola was about 15 minutes.

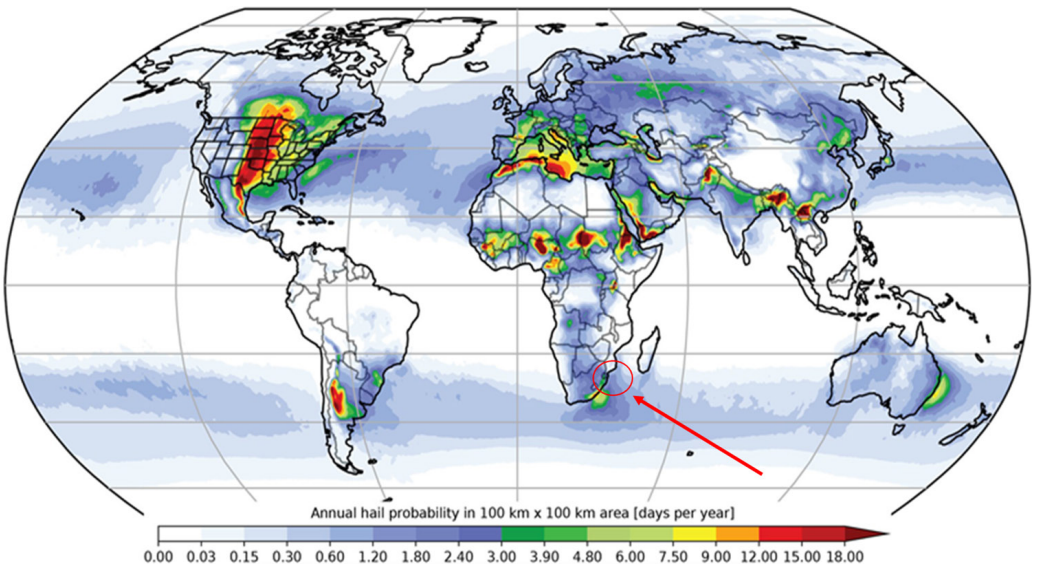

Figure 1
Annual probability of hail fall from 1979 to 2015 (Prein & Holland, 2018).

The urban agriculture in Maputo is the main source of income for a significant percentage of the population. In addition, vegetable cultivation contributes to a more balanced diet, especially for the producing households themselves: More than 10 000 people and their families (equivalent to 5% of Maputo's population) live directly from agricultural production in the so-called green zones (Halder et al., 2018). Another 40 000 people depend on activities associated with urban agriculture. Urban farmers in Maputo produce entirely cabbage and lettuce in several annual production cycles, both of which are in high demand. In the areas around Maputo city, Matola and Marracuene, it is estimated that 80% of the population grows home vegetables gardens with more diversified crops than the association's fields. The produce from these vegetables gardens is used for domestic consumption and small-scale sales. Thus, they contribute to the nutritional diversity of the producing families, providing various nutrients from vegetables, fruits and various vegetables and leaves (Halder et al., 2018). Currently, the phenomenon of hail fall has been reported to be quite devastating to agricultural fields. For example, the USA and India are among the countries with the highest hail crop losses (Klein et al., 2011).

In the study area, hailstorm phenomena are noted by local farmers as being rare. However, in recent years, a certain frequency of extreme weather events has been noted. In the memory of farmers in terms of slight destruction of crops by hail, they cite the nearest year (2010), with the current fall being the most notable. The frequency of hail fall phenomena with greater destructive capacity in places where it was previously uncommon has been reported in various parts of the world (Changon et al., 2009; Bal et al., 2014).

This new order of climate dynamics is pointed out as a major threat to the sustainability of the farming community. Thus, various techniques have been developed to protect crops from the destructive effect of hail. Among them, the ones that adjust to the reality of Maputo farmers are the following: (i) anti-hail nets, which are nets above the crops, are however not effective against strong hail storms and (ii) tree belts can significantly reduce hail damage in immediate areas since trees can directly intercept hail, they can also create a change in airflow and the downwind area is particularly protected from lateral hail drift, in addition to the fact that the wind speed will also be lower downwind from the shelter, as well as the total kinetic energy resulting from both vertical hail fall and wind speed will be lower (Bal et al., 2014).

Despite the various techniques developed to detect and monitor meteorological events, many challenges remain for the phenomenon of hail fall given its very local character, which requires a strong density of meteorological stations (Blair et al., 2017; Martins et al., 2017; Caldana et al., 2020).

In the case of the hail fall Communication of 01 June 2021, The National Meteorological Institute (INAM) announced the occurrence from late afternoon and tomorrow (02) of moderate to heavy rains, between 30 and 50 mm in 24 hours, accompanied by thunderstorms and high winds, in the provinces of Maputo, Gaza and Inhambane. The phenomenon is expected to affect all districts of the city and province of Maputo, in Gaza (Massingir, Limpopo, Chonguene, Massangena, Guíjá, Mandlakazi, Bilene and the towns of Chókwè and Xai-Xai), while in Inhambane the districts of Zavala and Inharrime will be affected. The note also states that the mentioned districts may be influenced by low temperatures during the next five days, with temperatures between 12 and 20 °C - Bulletin N.º 025/INAM-DAPT/250.2/2021. The communication model pointed out by INAM can be considered generic given the absence of local details about the atmospheric dynamics and risks. In this perspective the communication of environmental risks represents a situation in which the population should have access to information and, at the same time, present an involvement with prevention (Soriano et al., 2016). In the Mozambican reality, structural challenges persist for the dissemination of detailed meteorological information.

2. Methods and Materials

This work was conducted using a mixed approach methodology supported by the following methods and techniques:

i. Literature and documentary research were crucial in building the theoretical framework of the present research.

ii. Direct observation was crucial in describing the effects of hail on urban vegetables gardens with emphasis on cabbage, lettuce, and onion crops. These crops were selected because they are the most produced and marketed by local farmers along the northern strip of Matola and Maputo City, including south of Marracuene. Some kitchen gardens were observed within some backyards in the neighborhoods of Guava, Nkobe, Muhalaze and Cumbeza to assess their condition.

iii. The descriptive explanatory method was fundamental to describe the hailstorm phenomenon and more particularly to measure the size of the hail prevailing in the process of the fall, as well as to measure the characteristics created on the ground after the fall. The hail size measurement was done with a graduated ruler during the fall and the ground features were measured on the morning of the following day right after the night hail fall.

iv. The cartographic method was crucial to proceed with the geographical framing of the studied areas.

v. The interview was conducted on the following day (02-06-2021), where the authors visited the agricultural fields and vegetable gardens.

The aim was to assess the damage caused by hail in urban horticulture, with emphasis on lettuce, cabbage, and onion crops. We also interviewed some vegetable traders and buyers in Albazine, Magoanine C and Zimpeto market to assess the extent of vegetable supply by local producers and the prices charged. The prices and quantity of vegetables were monitored over the subsequent four days.

Climate and geo-environmental characteristics of the study area

The northern strip of the city of Maputo and Matola is inserted in the southern climatic region which is distinctly subtropical (Muchangos, 1999). On the coast, from the mouth of the Save River to the extreme south, the average annual rainfall varies between 800 and 1 000 mm while the average temperatures range between 22° and 24° C. In this region, the dry and cold season which lasts from April to September starts after the Inter-tropical Convergence Centre (ITC), in its movement towards the equator, has already crossed the northern boundary of Mozambique (Muchangos, 1999). In June and July, as the ITC is strongly displaced towards the Northern Hemisphere, southern Africa is influenced by the Subtropical anticyclone which is positioned over southern Africa, conditioning high pressure, subsidence of air currents, clear skies, and dry weather. Nights are cold and, in the mornings, there is a strong tendency for the formation of fog known as cacimbo (Muchangos 1999; Uamusse et al., 2020)

The movement of all barometric centers towards North at this time of the year allows the invasion of the South polar air in the southern region of Mozambique which in its advance towards the equator causes the rise of warm and light air. This

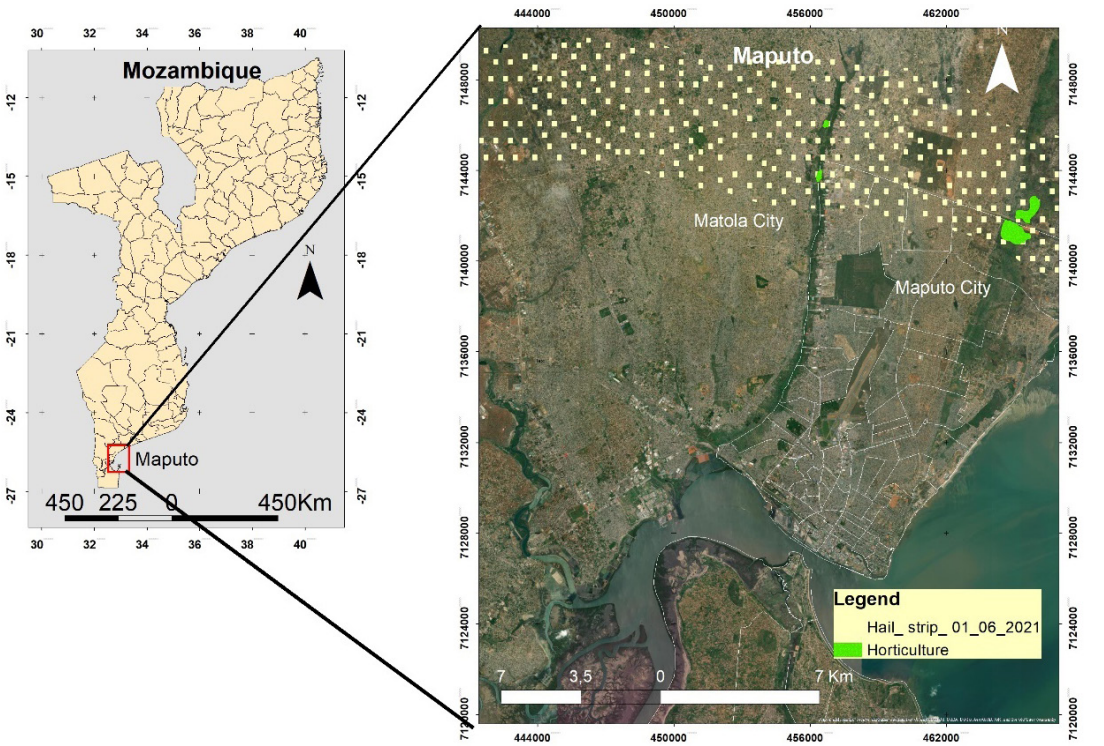

Figure 2
Location of the hailstorm belt and the cultivation areas of the studied horticultural crops.
Source: adapted by the authors based on the report of the area of hail fall (INAM - National Institute of Meteorology) and direct observation.

warm air can rise for several km until it reaches a low temperature and formation of ice blocks and hail falls (Muchangos, 1999).

On the day of the hailstorm occurrence (01 June 2021), Maputo city and Matola had a strong inter-tropical convergence at altitude, which caused the occurrence of thunderstorms and hail, however these phenomena are not normal during the winter month. The accumulated data on temperature and precipitation in Maputo and Matola from 1987-2017 show that during the dry period, especially from May to June, there are weak to moderate winds and low precipitation. However, in recent years, climate change is pointed out as a cause for the change in normal rainfall patterns in several parts of the globe and especially in Mozambique and Maputo city (Castán et al., 2013; Cabral et al., 2017).

Geographically, the study area is situated in the north of Maputo and Matola (Figure 3). It is characterized by a combination of rural and urban features, with agriculture along the lowlands being the most predominant practice. In geological terms, the strip where the hail-affected horticultural sites are located is underlain by heterogeneous materials, the most important of which are Holocene alluvial deposits consisting of metric alternations of well-calibrated sands (Vicente et al., 2006;) (Bernardo et al., 2022b) These deposits are interlaced with inland dune formations belonging to the Ponta Vermelha Formation (upper Pleistocene to lower Pleistocene and Machava Formation (upper Pleistocene) (Vicente et al. 2006; (Bernardo et al., 2022a; Bernardo et al., 2022c). These aspects give the strips between the dune's conditions suitable for growing vegetables.

Markets studied

The studied markets are located in the northern limit of Maputo city, and all are within the hail belt (Figure 3). Two of the markets are informal, namely: (i) Albazine informal market is characterized by being informal and is close to the horticultural production areas, supplies the population living in Guava and Albazine neighbourhoods; (ii) Magoanine C informal market is located in the northern limit of Maputo city and extends for a long stretch off Sebastião

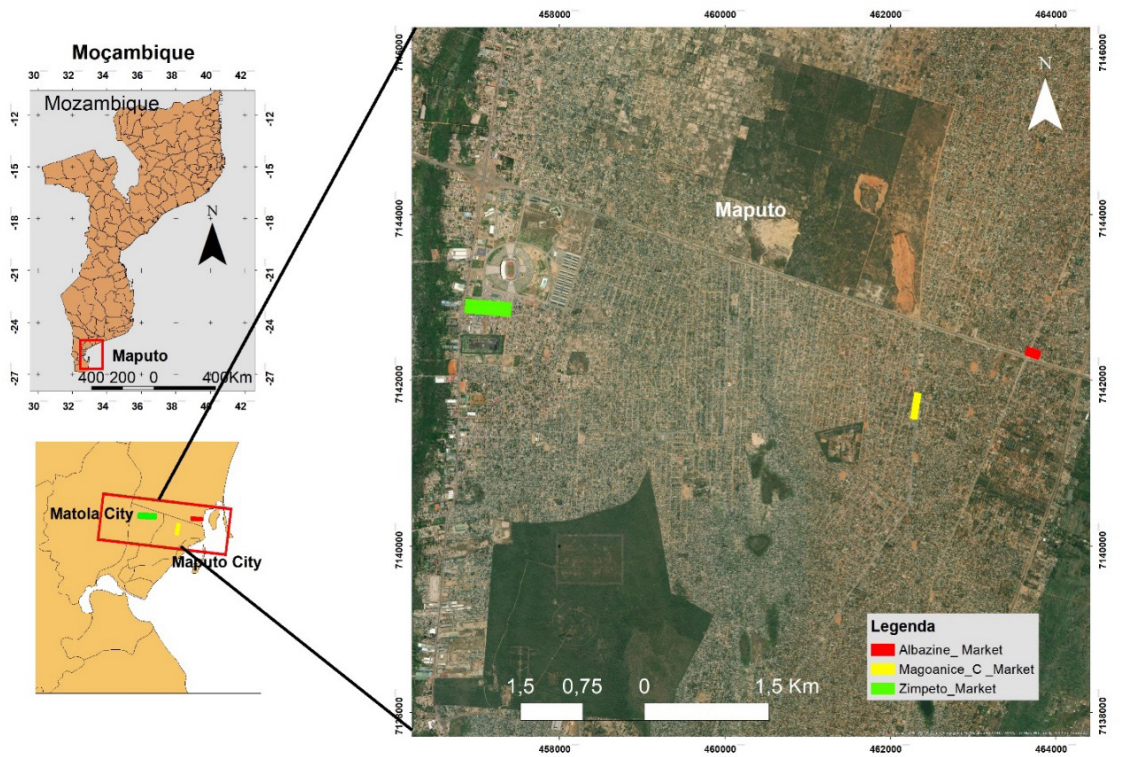

Figure 3
Markets studied in the north of Maputo city.
Source: By the authors, 2021

Marcos Mabote Avenue to the local square. It supplies most of the residents of Magoanine C. The Zimpeto Market is the largest market in Maputo, is characterized by the sale of various types of vegetables and is supplied by various production points in the city and province of Maputo, supplying the population from all over Maputo city and other parts of the country.

3. Results and discussion

Hailstorm Characteristics (01 June 2021- North of Maputo City and Matola)

The hailstorm recorded in the night of June 1, was characterized by hail fall of various dimensions (0.5 cm to 4.5 cm). The farmers interviewed in this research, said that this type of rain is not usual and historically hailstorm is extremely rare, existing in the memory a hailstorm of 26 October 2010, although not significant given the smaller size of the hail compared to the recent one. During the hailstorms, the entire ground was covered by hail, and that subsequently created thick layers of ice on the ground (Figure 4).

In this process, it was preceded by measuring the size of the hailstone and the following day by measuring the features created on the ground. These measurements allowed verifying the predominance of hailstones with sizes between 0.5 cm and 4.5 cm (Figure 5), and the created features with measurements between 0.5 cm and 5 cm (Figure 6).

Studies carried out in the USA and India show that the power of hail to destroy crops is directly related to the size of the hail, as well as the type of crop, with broadleaf crops being the most prone to destruction (Bal et al., 2014; Prein et al., 2018). Hail damage to agricultural fields is determined by the size ranges and number of hailstones falling per unit area, the strength of the wind during the event and the target property (Bal et al., 2014). Thus, we present some examples of distinct types of crops that were affected by hail fall over the studied area (Figure 7).

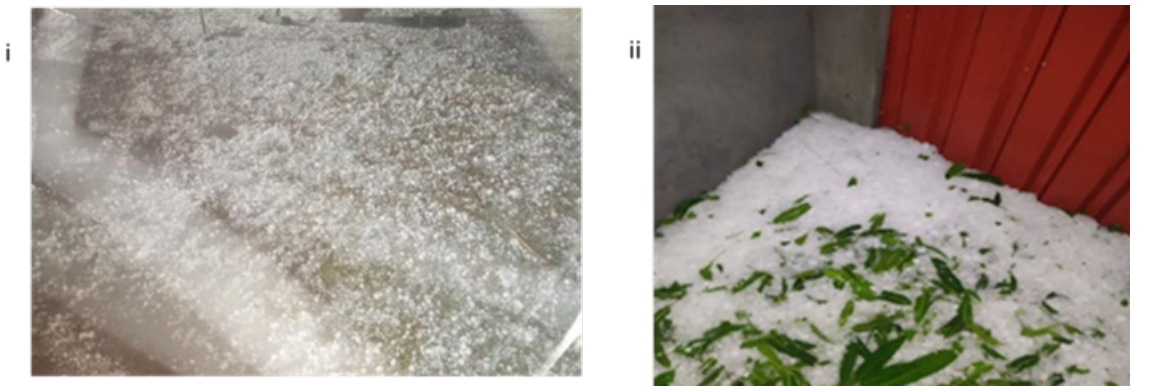

Figure 4
Process of hail falls and accumulation (i), (ii) accumulation of hail on 01 June 2021.

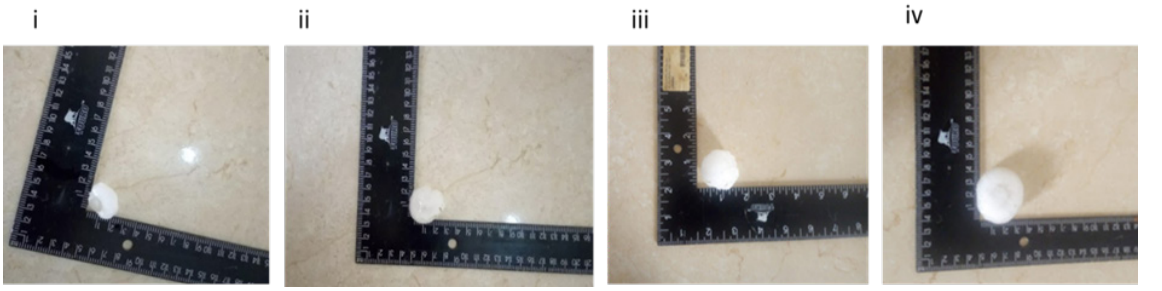

Figure 5
Hail sizes recorded on 01.06.2021 (Guava North of Maputo) (I) 1.25 cm; (ii) 2.25m; (iii) 2.5 cm and (iv) 4.5 cm.

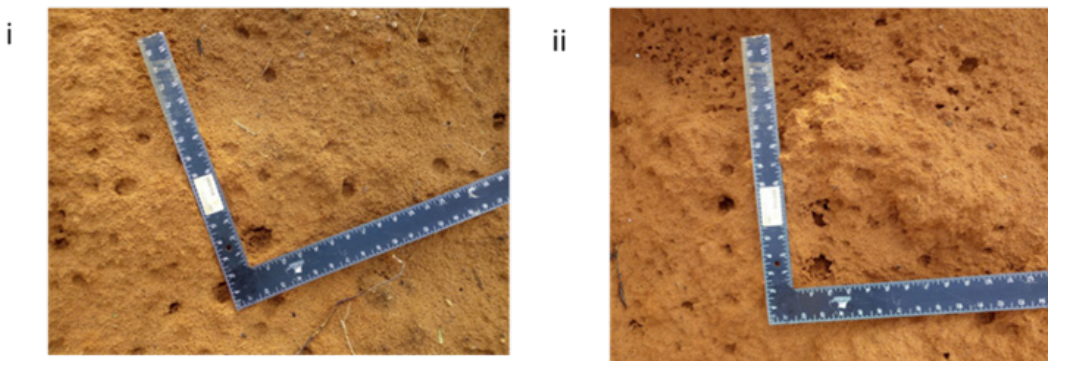

Figure 6
Features created on the ground by hailstorm on 01.06.2021. (i) 2.5 cm and (ii) 3.5 cm.

As for the destructive effect of different sizes of hail, hail with a diameter of 2.5 cm has a greater capacity to irreversibly destroy horticultural crops (Martins et al., 2017). Besides vegetables, studies show that hailstones of varied sizes can irreversibly destroy maize crops especially if they are affected at the pollination period (Klein et al., 2011). Another factor pointed out in the destructive effect of hail is the time of permanence on crops and soil. Regarding this factor, in this research visits were made to agricultural fields and vegetable gardens on the morning of 2 June, where it was noted the presence of undissolved hail around 10 am in several gardens (Figure 8).

The permanence of hail on the ground can cause serious effects not only on the vegetation cover but also on the adjacent ecosystems, given the radical change in the temperature of the soil and surrounding surfaces, including the appearance of diseases in the affected crops, as well as the rotting effect of some crops, such as cabbage (Bal et al., 2014).

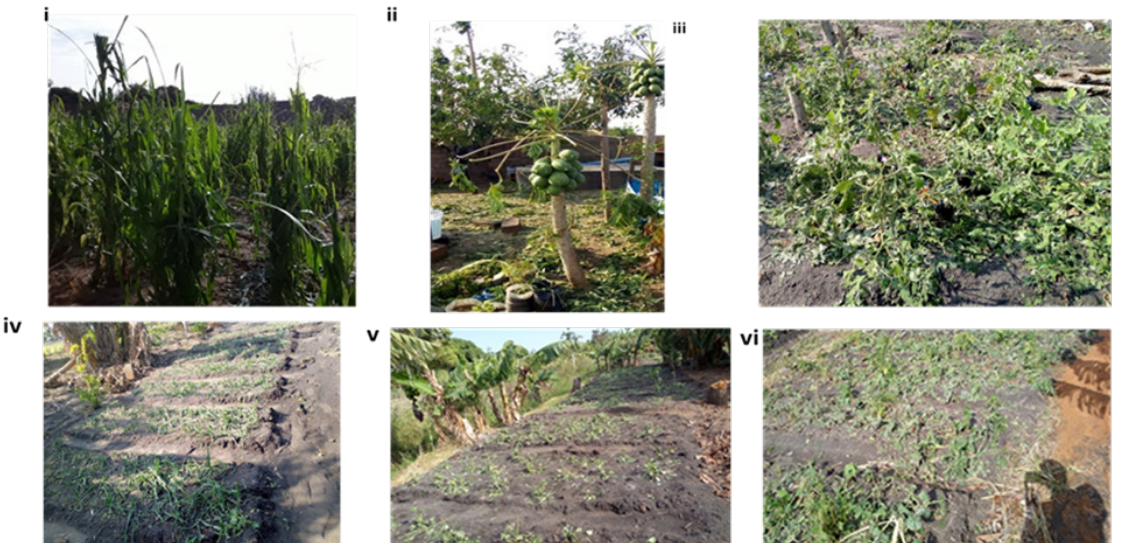

Figure 7
Destroyed cultures (i) Maize crop; (ii) Papaya crop; (iii) Aubergine crop; (iv) Onion crop; (v) Bean crop and (vi) Pumpkin leaf crop.

Figure 8
Hailstorm over the vegetable gardens on the morning of 2 June. (i) Hailstones in the vegetable gardens; ii and (iii) Hailstones accumulated on the beds of the commercial horticultural crops.

Impact of hailstorms on farmers in northern Maputo city and Matola

In this research, a semi-structured interview was applied to 4 local farmers with extensive agricultural areas affected by the hailstorm. The aim was to assess the immediate impact of the hailstorm on horticultural crops, as well as to understand the possible economic impacts.

All the farmers interviewed grow vegetables to supply local markets (Albazine, Magoanine C and Zimpeto). They have been practicing this activity for more than 10 years and it is the main source of livelihood for their families. Three women and one man were interviewed, totaling 4. The farmers interviewed own the most extensive gardens and located near the market of Albazine, Magoanine C and of the northwestern Maputo ring road (Matola).

In addition to the farmers interviewed, some associations' vegetable gardens were also observed but were not included in this research. The cultivation areas of the farmers studied have an extension of about 600 to 1 200 m^2. The four farmers interviewed said that to cultivate and maintain their vegetable fields they rely on seasonal helpers that vary from 1 to 3 depending on the type of intervention. The payment of the helpers is guaranteed by the sale of crops produced in the intervention areas.

In systematizing the impacts of hail, we can see two categories of impacts on the crops in the visited fields: (i) farmers who totally lost their crops

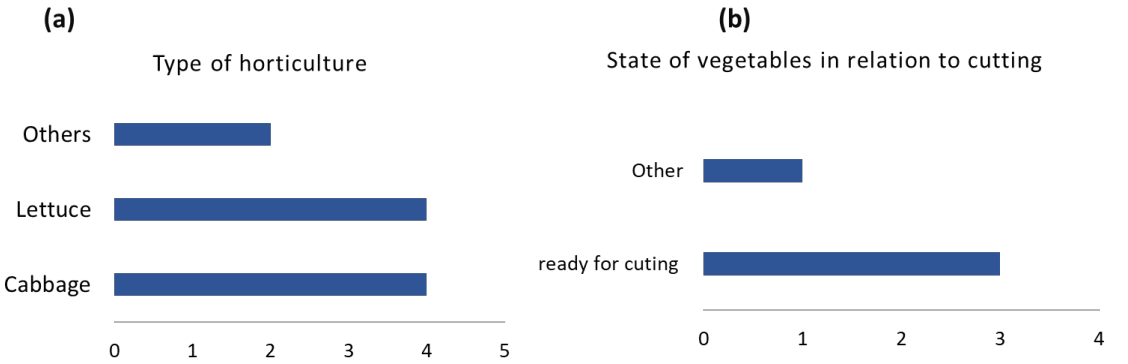

Figure 9
Impact of hailstorm (a) Types of vegetables and (b) Levels of vegetable destruction.

Figure 10
Crops destroyed by hail (i, ii, iii) lettuce crops destroyed; (iv and v) cabbage crops destroyed and (vi) onions destroyed

and (ii) farmers who partially lost their crops. The farmers who reported the impact of almost total loss of crops mainly devoted to cabbage and lettuce crops, however onion and bean crops were also severely destroyed, which shows that hail totally covered the affected areas during the fall (Figure 9).

During field observation cabbage and lettuce crops were the most destroyed by hail fall due to their wide leaf structure and direct exposure to hail impact (Figure 10).

In addition to the larger leaf structure of the most affected crops, observation and interviews allowed us to understand that these crops were at their highest level of development, i.e., ready for cutting and sale.

Some socio-economic impacts were translated in the form of statements in the following terms:

"These cabbages and lettuces should have been cut yesterday, but as I sprayed the day before yesterday, I put it off until today and unfortunately during the night there was this hail disaster" (2).

"The lettuce crops that I lost were all paid for and each of them cost 500 mts" (3).

"All the cabbage crops were all sold and each one cost 300 mts, but they were all lost" (2).

"Another 40 lettuce beds and 32 cabbage beds were destroyed in this agricultural field" (1).

In parallel the fields that recorded partial losses are characterized by producing mixed crops of varied

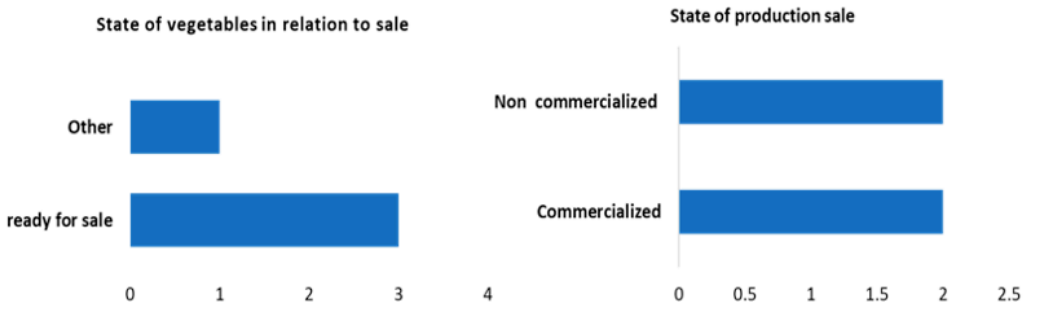

Figure 11
Socio-economic impact of hail (a) Developmental stage of affected and (b) status of the sale of impacted horticulture crops.

Figure 12
(i) Crops destroyed due to exposure during hail fall and (ii) Crops less damaged by hail given the protective factor of other crops of greater height.

sizes. Another aspect observed is that crops intercropped with those of greater height had less damage, as the taller crops served as protectors to the direct impact of hail (Figure 12).

During the interviews and the observation of the agricultural fields, we could see a strong shock regarding the consequences and the destructive effect caused by hail. This revealed the absence of experience of similar destruction among local producers, which we consider in this research as a possible burden of climate change. In this research, some kitchen gardens in some neighborhoods (Guava, Nkobe, Muhalaze and Cumbeza) affected by the hailstorm were also observed. From these observations, it was concluded that there are two types of impacts: (i) the destruction of kitchen gardens that help in the diet and (ii) the destruction of gardens that are sources of economic support of families.

In all types of impacts, the destruction was characterized by almost total loss of crops, consisting of cabbage, lettuce, onions, beans, maize, pumpkin leaf, and papayas (Figure 13).

Price effects

After the hailstorm fell on the vegetable growing areas, there was a slight change in the number of vegetables sold for 50 meticais. This change occurred in all three markets studied. However, the market that had the most impact on the decrease in the number of vegetables offered was the informal market in Albazine. Since the main source of vegetable supply at this market is local farmers, whose family gardens were heavily destroyed by the hailstorm. At this market, traders started using the kitchen gardens further south to supply the local market, where the price went from 500 meticais to 800 meticais. This forced change in supply source,

Figure 13
Home horticulture affected by hailstorm. (i) Cabbage crop destroyed in Muhalaze; (ii) Cabbage crop affected in Nkobe; (iii) Cabbage crop affected in Kumbeza and (iv) Lettuce crop destroyed in Guava.

together with the increase in prices by farmers, was identified as the main cause of the reduction in the quantity of lettuce and cabbage offered for 50 meticais (Figure 14).

In Zimpeto and Magoanine C market, the fluctuation of vegetable supply was not significant compared to the informal market in Albazine. In Albazine market, the main source of supply is the local vegetable gardens that were severely destroyed by the hailstorm. In Zimpeto market, the sources of supply from the vegetable gardens are quite heterogeneous, but part of the local farmers were affected, which had some influence on the oscillation of the number of lettuce and cabbage stems offered in the following two days after the hailstorm (Figure 15).

Consumers' perception of the impact of hail on the supply of horticultural

The impact of hail on vegetable supply in the studied markets, some consumers interviewed in a semi-structured way, and stated that the amount of lettuce and cabbage bought for 50 meticais in the three days after the hail fall decreased slightly but given that two weeks before the hail fall the supply price was like the current supply the changes did not seem significant. This reality results from the fact that local agriculture is traditional and dependent on natural conditions and vegetables in local agricultural fields develop very easily in the cool period that characterizes the end of April and extends until August, thus allowing a greater supply for the vegetable market (Halder et al., 2018). On the sixth day after the hailstorm, there was a rapid normalization of the quantity of vegetables offered in all markets. This minimization of the impact of hail on the supply of vegetables results from the fact that June is the beginning of the period of greatest supply of these vegetables from urban gardens scattered in the various growing areas in the city and province of Maputo.

Figure 14
Demonstration of the number of lettuce and cabbage stalks offered on the day before hail fall (i and iii) and (ii and iv) after hail fall.

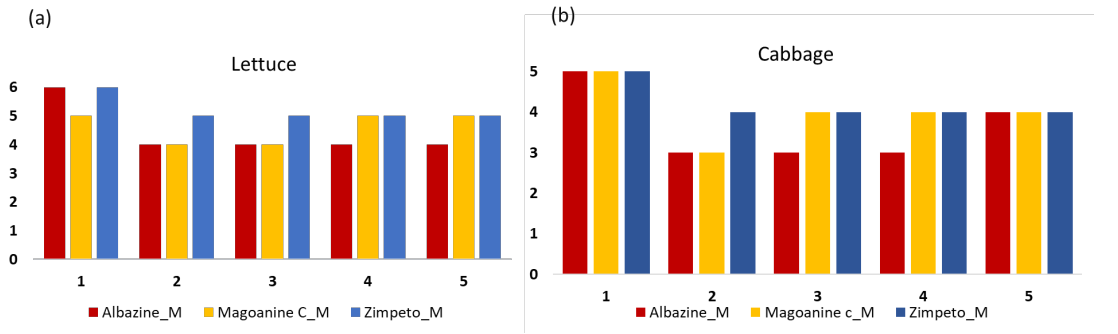

Figure 15
Number of stems offered in the markets after the hailstorm (a) lettuce and (b) cabbage.

4. Conclusion

Urban agriculture is one of the activities most affected by extreme weather events and in particular hail in various parts of the world including Mozambique where it is recorded with relative frequency in recent years. In this research, the adverse impacts of the 1 of June 2021, hailstorm on urban agriculture in northern Maputo and Matola were highlighted. Where it was possible to understand that the fall of hail of 0.5 to 4.5 cm generated the partial destruction and destruction of vegetable gardens and on the crops of cabbage and lettuce.

This destruction had immediate repercussions for producers, retailers, and consumers of home gardens. Farmers lost almost all the crops that were ready for cutting and sale, and in other cases, lost more than 40 beds already sold, without their cut and transport to the markets. This influenced the number of vegetables offered for 50 meticais to local consumers.

The markets of Albazine, Magoanine - C were the ones that registered more oscillations in the number of vegetables offered, given the strong dependence on local vegetables severely affected by the hailstorm. In turn, Zimpeto market registered slight oscillations, given the strong heterogeneity of the supply sources.

Monitoring the vegetable supply process in the studied markets after the hailstorm showed a stabilization six days later caused by the strong supply of vegetables from neighboring producers.

This research suggests the need for a thorough monitoring of meteorological events, considering the dynamics imposed by climate change, as well as the improvement of the communication system of environmental risks for the most vulnerable population.

5. Credit author statement:

Conceptualization, Bernardino Bernardo, Elisa Nhambire, Alice Freia, Octávio Manuel de Jesus; methodology Bernardino Bernardo, Elisa Nhambire, Alice Freia, José Júlio Guambe, Zacarias Ombe, Gustavo Dgedge; formal analysis Bernardino Bernardo, Elisa Nhambire, Alice Freia, Octávio Manuel de Jesus,

investigation Bernardino Bernardo, Elisa Nhambire, Alice Freia, Octávio Manuel de Jesus; writing—original draft preparation Bernardino Bernardo, Elisa Nhambire, Alice Freia, Octávio Manuel de Jesus ; writing—review and editing Bernardino Bernardo, Elisa Nhambire, Alice Freia, Octávio Manuel de Jesus José Júlio Guambe, Zacarias Ombe and Gustavo Dgedge.

6. Declaration of Competing Interest:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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