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*Full Length Research Paper*

# Distribution patterns of cultivated watermelon forms in Zimbabwe using DIVA-GIS

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**Identification of potential areas and regions for collection of watermelon germplasm is pivotal for better utilization of the available diversity. DIVA-GIS were used on all watermelon collections in the National Genebank of Zimbabwe to explore the pattern of distribution of two forms of watermelons; sweet watermelon (*Citrullus lanatus* var. *lanatus*) and cow-melon (*Citrullus lanatus* var. *citroides*). DIVA-GIS analysis revealed that most watermelon accessions have been collected at altitudes ranging from 160 to 1550 m above sea level, and that sandy loam and sand soils apparently are preferred. Distribution of the two forms of watermelons across soil types, altitudinal ranges and provinces is similar. In order to maintain watermelon diversity, promotion of *in-situ* or on-farm conservation of watermelon genetic resources using best practices in traditional farming system is recommended. Furthermore, this should be complemented by *ex-situ* conservation through gap collection missions in order to identify and document additional diversity hotspots.**

**Key words:** DIVA-GIS, sweet watermelon, cow-melon, *Citrullus lanatus*, *in-situ*, on-farm conservation.

## INTRODUCTION

Watermelon (*Citrullus lanatus*), plays an important role as a food security crop in the semi-arid areas of Zimbabwe, where droughts and erratic rainfalls affect agricultural production. The semi-arid areas of the country are host to over 75% of the Zimbabwean populace, wholly depending on subsistence farming for their livelihoods and survival. The semi-arid areas cover agro-ecological regions III, IV and V, as described by Rukuni and Eicher (1994), with an estimated 88.9% (32,510,000 ha) of the area of Zimbabwe. In these areas, access to inter- and intra-specific watermelon diversity is a survival strategy used by farmers to ensure food security. Farmers have thus developed landraces to meet specific purposes for human use (dessert, oil, seed and porridge) and animal feed. By contrast, they have not adopted modern varieties despite being exposed to these. Two botanical varieties of watermelon such as *C. lanatus* var. *lanatus* the sweet watermelons and *C. lanatus* var. *citroides* (citron melons or cow-melons) are found in cultivation. The ancestral forms of watermelon (also known as the Tsamma melons belonging to var. *citroides*) are also found in Southern Africa, in the wild. Southern Africa is generally regarded as the centre of origin for watermelon (Dane and Liu, 2007).

The conservation of biodiversity is critical for sustaining a growing population and enhancing global nutrition (Frankel, 1977). Genetic resources of indigenous plant species are important for crop and dietary diversity. Efforts to sustain population demands on agricultural productivity will necessitate an increase in the effective use of germplasm during plant improvement (Pistorius, 1997). Under the regional programme of Southern Africa Development Cooperation Genetic Resources Centre and National Plant Genetic Resources Centre Network, watermelon has been considered an underutilized crop, implying that its full potential has not been explored. It is

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therefore considered a mandate crop for conservation in the whole of the Southern African region.

Traditional local cultivars embody substantial diversity, and continue to provide an essential component of sustainable crop production for many of Africa's poor. The diversity of watermelon uses in Africa as shown by various studies for instance in Nigeria (Badifu, 1993); Namibia (Maggs-Kölling et al., 2000); Cote d'Ivoire (Loukou et al., 2007); Benin (Achigan-Dako et al., 2008); Mozambique (Munisse et al., 2011) and Mali (Nantoumé, 2011) is a clear indication of its importance in human diets. The link between local watermelon diversity and diverse uses, provide the rationale for enhancing the availability and use of local crop varieties in the arid and semi-arid regions of sub-Saharan Africa. Often, due to the drought-tolerant nature of watermelon, its importance as a food source is linked to agro-ecological conditions. Apart from diverse uses, farmers also need watermelon diversity for security against unpredictable conditions and to enhance optimum use of their resource base.

Farmers in traditional agriculture depend on informal systems to supply local watermelon seeds for cultivation and they maintain much of this diversity within their agroecosystems (on-farm). However, adequate access to diverse varieties is limited by lack of information on these varieties, placing traditional varieties at a disadvantage relative to varieties from the formal sector. In order to support and strengthen the conservation and use of watermelon, there is a need to gain insight into the genetic, ecological and geographic patterns associated with its distribution. The status of traditional watermelon cultivation and on-farm conservation in Zimbabwe is insufficiently documented. Limited information also exists on the diversity of the genus *Citrullus* and the extent of its distribution in Zimbabwe. With increasing commercial production of sweet watermelons from neighbouring countries (South Africa in particular), there is a potential risk that cultivation of indigenous, well-adapted landraces may be abandoned as farmers wish to try sweeter, modern cultivars through trade.

Proper identification and collection of plant material is an important step for effective conservation and utilization of the available germplasm. The use of DIVA-GIS has been designed to assist the plant genetic resources and biodiversity communities to map the range of distribution of species in which they are interested (Hijmans et al., 2002). Such analyses are essential for identification of potential areas of diversity and collection gaps for consideration when designing future collection missions. In the present study, DIVA-GIS was used to analyse and map cultivated watermelon forms in Zimbabwe.

## MATERIALS AND METHODS

Data for DIVA-GIS use (Table 1 and 2) was gathered from passport information recorded on a total of 89 watermelon accessions stored in the National Genebank of Zimbabwe; collector's number (CollNo), type of watermelon (Type), province (Prov), name of farmer, longitude (Long), latitude (Lat), altitudinal range (m) and soil type. Taxon information recorded on accessions collected was mainly watermelon types (Type), aimed at separating watermelons into two major forms (SWM sweet watermelons, and CWM cow-melons) based on indigenous knowledge derived from local farmers. The separation of sweet watermelons (*C. lanatus* var. *lanatus*) and cow-melons (*C. lanatus* var. *citroides*) were further confirmed by molecular studies (Mujaju et al., 2010; Mujaju and Nybom, submitted).

The sampling of watermelons was carried out around the whole country as part of multi-species collection trips. These collections mostly followed the main roads, with stops every 5 kilometres for collecting new material. An additional targeted collection mission was performed in Masvingo province (Chitanga village) for the purposes of assessing the watermelon diversity within a single community (Mujaju and Nybom, submitted). Analysis of the spatial distribution of watermelon accessions collected throughout Zimbabwe was done using DIVA-GIS version 5.2 (Hijmans et al., 2002). The analysis involved generating maps of the distribution pattern of watermelon in relation to soil type and altitudinal range with the help of point-to-grid option applying simple method. Simple method assign watermelon collection points to the grid cell they fall in.

## RESULTS AND DISCUSSION

Diversity analysis of the existing collections using DIVA-GIS (Figure 1), demonstrated that Masvingo province had the highest number of watermelon accessions. This province is situated in a drought-prone area, with average rainfall of 600 mm per annum. However, the high number of observations in Masvingo province was mostly due to the targeted collection in Chitanga village (21°17´S, 30°45´E), where 29 accessions were collected. While arguments about assessing genetic diversity by the number of accessions exists, previous studies on the same accessions (Mujaju et al., 2010; Mujaju and Nybom, submitted; Mujaju et al., submitted) using dominant molecular markers have revealed individual accession profiles. Consequently, the distribution of watermelon reflects the existence of diverse forms of watermelon in cultivation. Watermelon cultivation has been reported to be prevalent in drought-prone, semi-arid areas with an annual rainfall below 650 mm (Mujaju et al., 2010). If therefore further targeted collections are done in other drier provinces of the country, they are expected to have similar numbers of watermelon farming communities as Masvingo province. Subjecting all provinces to the same sampling regime (applied during multiple species germplasm collection) by excluding watermelon collections from Chitanga village, provides a fairly similar number of watermelon observations across the drier provinces of Matabeleland South, Matabeleland North, Midlands, Mashonaland West and Masvingo. A multi-species germplasm collection mission focuses on collecting diverse types of crops which limits the quantity of each crop collected. Other provinces like Harare, Bulawayo, Mashonaland Central, Mashonaland East and Manicaland, which are found within the high-rainfall belt of the country, only exhibited a few collections each

**Table 1.** List of watermelon material from the National Genebank of Zimbabwe.

| CollNo | Type | Prov | Long | Lat |
|---|---|---|---|---|
| MMM014 | CWM | Mashonaland Central | 31.34885 | -16.3828 |
| MMM036 | CWM | Mashonaland Central | 31.34885 | -16.3828 |
| MMM049 | CWM | Mashonaland West | 29.49436 | -16.5986 |
| MMM062 | CWM | Mashonaland West | 30.09509 | -17.4604 |
| MMM063 | CWM | Mashonaland West | 30.09509 | -17.4604 |
| MMM064 | CWM | Mashonaland West | 30.09509 | -17.4604 |
| MMM068 | SWM | Mashonaland West | 29.53672 | -17.3921 |
| MMM076 | SWM | Midlands | 28.59085 | -17.4275 |
| MMM077 | SWM | Midlands | 28.59085 | -17.4275 |
| MMM084 | CWM | Midlands | 28.58981 | -17.5676 |
| MMM101 | CWM | Midlands | 28.52666 | -18.1119 |
| MMM102 | CWM | Midlands | 28.52666 | -18.1119 |
| MMM103 | CWM | Midlands | 28.52666 | -18.1119 |
| MMM112 | CWM | Matabeleland North | 28.06491 | -17.2781 |
| MMM123 | CWM | Matabeleland North | 27.41267 | -17.5787 |
| MMM127 | CWM | Matabeleland North | 27.41706 | -17.5787 |
| MMM133 | CWM | Matabeleland North | 27.0647 | -18.1108 |
| MMM156 | SWM | Midlands | 29.119 | -19.0319 |
| MMM162 | SWM | Midlands | 29.57793 | -19.0771 |
| MMM170 | CWM | Midlands | 29.17218 | -19.0814 |
| MMM177 | SWM | Matabeleland South | 28.58826 | -19.5857 |
| MMM179 | CWM | Matabeleland South | 28.58826 | -19.5857 |
| MMM180 | CWM | Matabeleland South | 28.58826 | -19.5857 |
| MMM181 | CWM | Matabeleland South | 28.58826 | -19.5857 |
| MMM186 | CWM | Matabeleland North | 27.32282 | -19.2885 |
| MMM190 | CWM | Matabeleland South | 27.50096 | -20.3042 |
| MMM191 | SWM | Matabeleland South | 27.50096 | -20.3042 |
| MMM194 | SWM | Matabeleland South | 27.39455 | -20.2605 |
| MMM202 | CWM | Matabeleland South | 27.39455 | -20.2605 |
| MMM203 | CWM | Matabeleland South | 27.39455 | -20.2605 |
| MMM210 | SWM | Midlands | 29.00014 | -20.2806 |
| MMM211 | CWM | Midlands | 30.10352 | -20.2806 |
| MMM216 | CWM | Midlands | 30.27996 | -20.4482 |
| MMM218 | CWM | Masvingo | 30.42494 | -20.4453 |
| MMM219 | CWM | Masvingo | 30.42494 | -20.4453 |
| MMM227 | CWM | Mashonaland East | 31.3834 | -18.2301 |
| MMM228 | SWM | Mashonaland East | 31.3834 | -18.2301 |
| MMM253 | SWM | Masvingo | 31.30661 | -21.1896 |
| MMM265 | SWM | Masvingo | 32.06837 | -20.5994 |
| MMM274 | CWM | Manicaland | 32.35514 | -18.4688 |
| MMM314 | CWM | Mashonaland Central | 31.54382 | -17.1409 |
| MMM321 | SWM | Matabeleland North | 27.32282 | -19.2885 |
| MMM322 | SWM | Matabeleland North | 27.32282 | -19.2885 |
| MMM323 | SWM | Matabeleland North | 27.32282 | -19.2885 |
| MMM324 | SWM | Matabeleland North | 27.32282 | -19.2885 |
| MMM325 | SWM | Matabeleland North | 27.32282 | -19.2885 |
| MMM326 | SWM | Matabeleland North | 27.32282 | -19.2885 |
| MMM328 | SWM | Mashonaland West | 30.09509 | -17.4604 |
| MMM329 | SWM | Mashonaland West | 30.09509 | -17.4604 |
| MMM330 | SWM | Mashonaland West | 30.09509 | -17.4604 |
| MMM331 | SWM | Mashonaland West | 30.09509 | -17.4604 |

**Table 1.** Contd.

| | | | | |
|---|---|---|---|---|
| MMM332 | SWM | Matabeleland South | 27.39455 | -20.2605 |
| MMM333 | SWM | Matabeleland South | 27.39455 | -20.2605 |
| MMM334 | SWM | Matabeleland South | 27.39455 | -20.2605 |
| MMM338 | CWM | Matabeleland South | 27.39455 | -20.2605 |
| MMM339 | CWM | Matabeleland South | 27.39455 | -20.2605 |
| CM1 | SWM | Masvingo | 30.7542 | -21.2943 |
| CM2 | SWM | Masvingo | 30.7542 | -21.2943 |
| CM3 | CWM | Masvingo | 30.7542 | -21.2943 |
| CM4 | CWM | Masvingo | 30.7542 | -21.2943 |
| CM9 | SWM | Masvingo | 30.75538 | -21.2921 |
| CM10 | SWM | Masvingo | 30.75538 | -21.2921 |
| CM11 | SWM | Masvingo | 30.75538 | -21.2921 |
| CM12 | SWM | Masvingo | 30.75538 | -21.2921 |
| CM13 | CWM | Masvingo | 30.75538 | -21.2921 |
| CM14 | CWM | Masvingo | 30.75538 | -21.2921 |
| CM15 | SWM | Masvingo | 30.75538 | -21.2921 |
| CM16 | SWM | Masvingo | 30.75538 | -21.2921 |
| CM17 | SWM | Masvingo | 30.75538 | -21.2921 |
| CM18 | SWM | Masvingo | 30.75538 | -21.2921 |
| CM19 | SWM | Masvingo | 30.75538 | -21.2921 |
| CM20 | SWM | Masvingo | 30.75538 | -21.2921 |
| CM21 | SWM | Masvingo | 30.75538 | -21.2921 |
| CM22 | SWM | Masvingo | 30.75538 | -21.2921 |
| CM29 | CWM | Masvingo | 30.75417 | -21.2885 |
| CM30 | CWM | Masvingo | 30.75417 | -21.2885 |
| CM31 | CWM | Masvingo | 30.75417 | -21.2885 |
| CM32 | CWM | Masvingo | 30.75417 | -21.2885 |
| CM33 | CWM | Masvingo | 30.75417 | -21.2885 |
| CM38 | SWM | Masvingo | 30.75417 | -21.2885 |
| CM39 | SWM | Masvingo | 30.76422 | -21.2914 |
| CM40 | SWM | Masvingo | 30.76422 | -21.2914 |
| CM41 | SWM | Masvingo | 30.76422 | -21.2914 |
| CM42 | SWM | Masvingo | 30.76422 | -21.2914 |
| CM43 | SWM | Masvingo | 30.76422 | -21.2914 |
| CM44 | CWM | Mashonaland East | 32.41667 | -17.25 |
| CM45 | SWM | Masvingo | 30.75 | -21 |
| CM46 | CWM | Masvingo | 30.75 | -21 |
| CM47 | CWM | Masvingo | 30.75 | -21 |

SWM: Sweet watermelon; CWM: Cow-melons.

suggesting that watermelon is grown mainly in a drier habitat. GIS has been successfully used in identifying areas of high diversity, e.g., for phaseolus bean (Jones et al., 1997), wild potatoes (Hijmans et al., 2000) and black pepper (Parthasarathy et al., 2006). The watermelon collection mission undertaken in Masvingo province in 2009 revealed a potential risk faced by farmers in maintenance of diversity on-farm. Most of the active farmers involved were elderly, whereas most of the young family members were reported to be working in towns (Mujaju and Nybom, submitted). This skewed age distribution implies a risk concerning the continuity of traditional knowledge about crop cultivation (Montes-Hernandez et al., 2005) and may advance the existence of superstitious myths that hinder seed exchange (Mujaju and Nybom, submitted). Until now, the common practice of exchanging seeds, and the different methods for watermelon planting that can promote gene flow across fields, may have helped to decrease the potential loss of heterozygosity within watermelon forms. In the closely related crop squash, the exchange of seeds for planting among farmers was considered useful as a method to

**Table 2.** The number of sweet watermelon and cow-melon accessions found within a particular soil type, altitudinal range and province in Zimbabwe. Numbers within parentheses indicate accessions collected in Chitanga village in Masvingo province.

| Parameter | Sweet watermelon | Cow-melon |
|---|---|---|
| Soil type | | |
| Clay | 1 | 3 |
| Clay loam | 2 | 5 |
| Loam | 4 | 4 |
| Sandy loam | 33 (20) | 25 (9) |
| Sand | 6 | 6 |
| Altitudinal range (m) | | |
| 158 – 620 | 22 (20) | 9 (9) |
| 620 – 1081 | 3 | 13 |
| 1081 – 1543 | 20 | 19 |
| 1543 – 2004 | 1 | 2 |
| 2004 – 2466 | 0 | 0 |
| Province | | |
| Mashonaland Central | 0 | 3 |
| Mashonaland West | 5 | 4 |
| Mashonaland East | 1 | 2 |
| Masvingo | 23 (20) | 13 (9) |
| Manicaland | 0 | 1 |
| Midlands | 5 | 7 |
| Matabeleland North | 6 | 5 |
| Matabeleland South | 6 | 8 |
| Harare | 0 | 0 |
| Bulawayo | 0 | 0 |

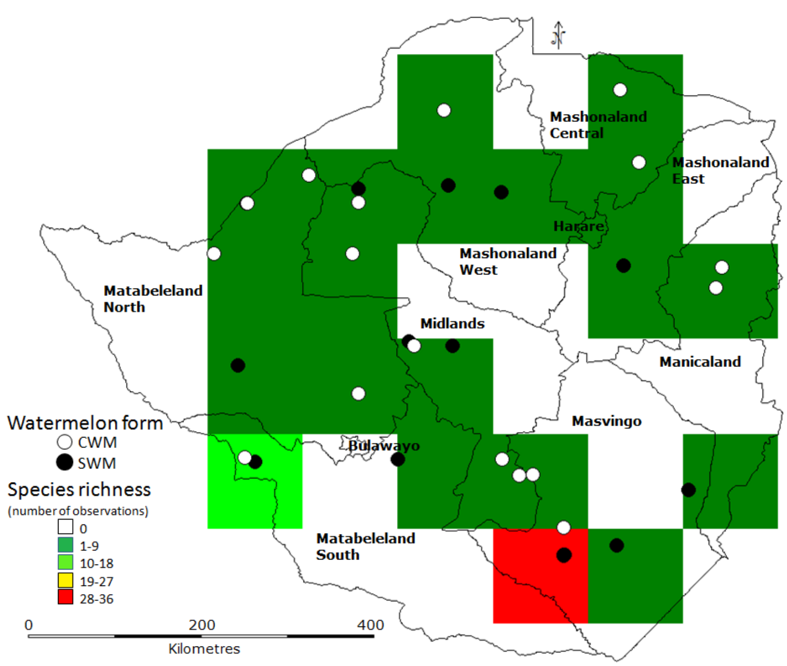


**Figure 1.** Distribution and number of accessions in the Zimbabwe genebank for the two watermelon forms using DIVA-GIS. CWM cow-melon, SWM sweet watermelon. Names of provinces are inserted.

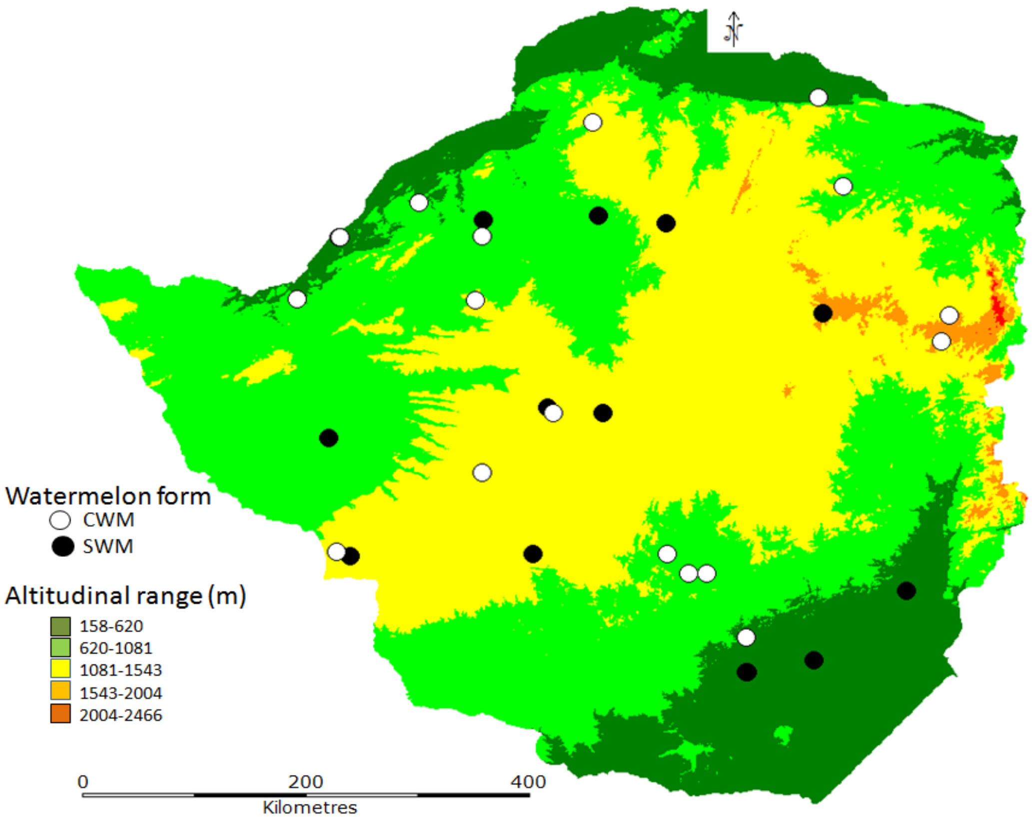


**Figure 2.** Distribution of collections in the Zimbabwe genebank for the two watermelon forms according to altitude using DIVA-GIS. CWM cow-melon, SWM sweet watermelon.

increase the genetic basis of squash germplasm (Montes-Hernandez et al., 2005). Use and benefits of increasing diversity by exchanging seeds for planting hasbeen reported also in local varieties of cowpea in Africa (Uguru, 1998). Distribution patterns of the two watermelon forms across soil types, relative to altitudinal ranges and provinces in Zimbabwe were assessed (Table 2, Figure 2 and 3). The maps for the distribution of watermelons according to soil type (Figure 3) and altitudinal range (Figure 2) showed that most accessions had been collected at 158 to 620 m and 1081 to 1543 m above sea level. The latter range harbored 22 sweet watermelons and 9 cow-melons whereas the former was host to 20 sweet watermelons and 19 cow-melons but most of these came from one village, Chitanga in Masvingo province (Table 2). The altitudinal range 620 to 1081 m harbored 3 sweet watermelons and 13 cow-melons. Very few accessions were obtained for the range 1543 to 2004 m (1 sweet watermelon and 2 cow-melons) and none at even higher altitudes. This is most likely due to the increase in rainfall above 1543 m, which is unfavorable for the growing of watermelons. Apart from Chitanga village, where watermelon cultivation was initiated only about ten years ago as a result of the land redistribution, almost all accessions were thus collected at medium high altitudes from 600 to 1600 m. Sandy loam soils followed by sandy soils are predominant in the areas where watermelon was collected (Figure 3). Watermelon has been reported to perform especially well under savannah environments in well-drained sandy loam soil (Van der Vossen et al., 2004).

The distribution map also demonstrates areas where very little explorations have been undertaken, suggesting gaps in collections. This has an implication on conservation which should also focus on the need for comprehensive collection of watermelon germplasm in order to identify and document additional diversity hotspots. Any conservation strategy that seeks to promote on farm conservation, should also consider long-term sustainability, where security of greater diversity results from the complementary application of *in-situ* and *ex-situ* techniques (Maxted et al., 2002).

## Conclusion

The two cultivated forms of watermelon are apparently grown in the same habitats in Zimbabwe. These habitats are characterized by sandy soils and low rainfall, while altitudes vary substantially; from just above sea level to at

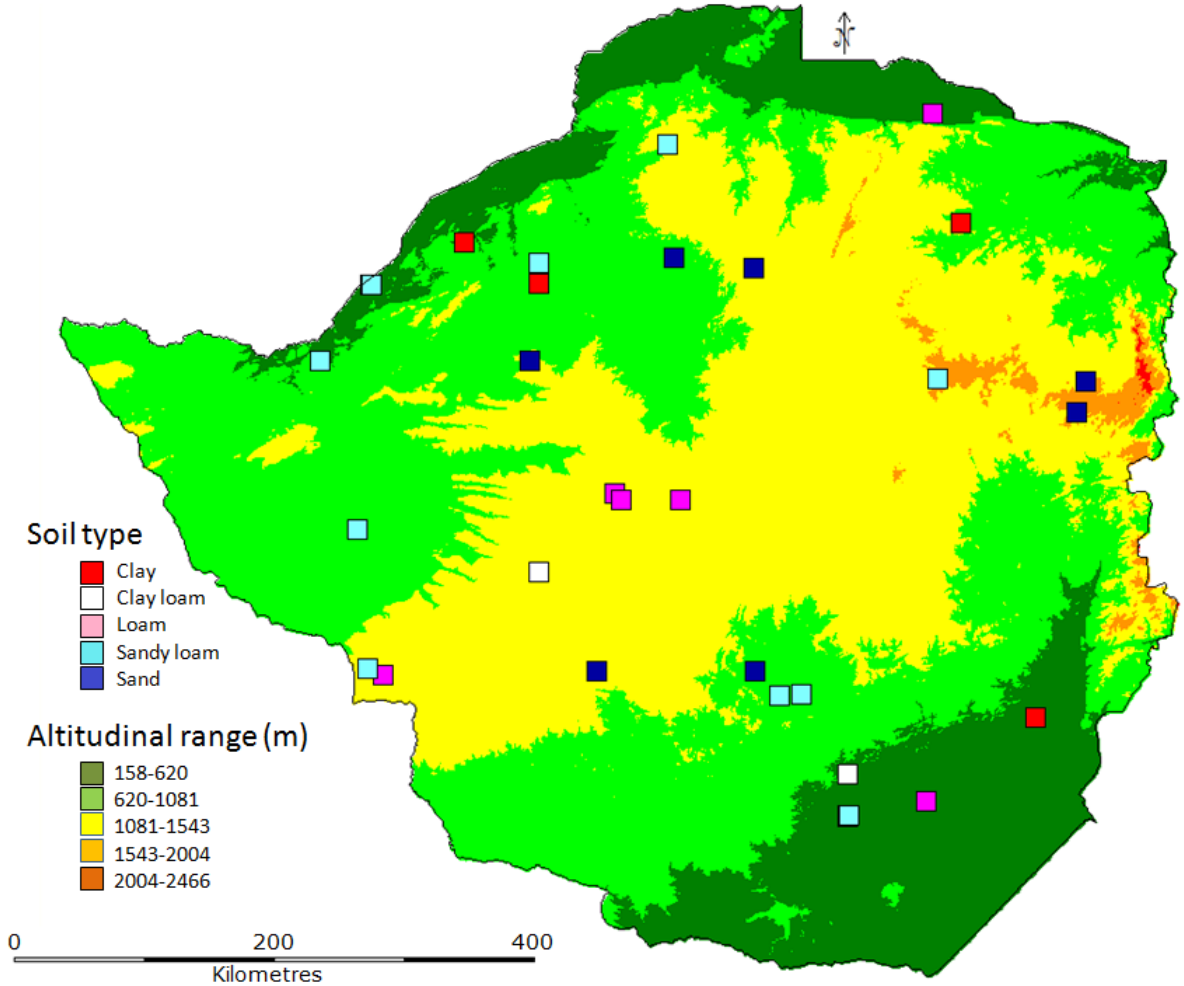


**Figure 3.** Distribution of watermelon collections in the Zimbabwe genebank according to soil types and relative altitudinal range using DIVA-GIS.

least 1500 m. Future collection missions should focus on those areas where the distribution map shows major gaps. A detailed study based on climatic data is warranted to predict the climatic and ecogeographic conditions required for watermelon and also to forecast its distribution in other parts of Zimbabwe.

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