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Reasons and Processes Leading to the Erosion of Crop Genetic Diversity in Mountainous Regions of Georgia

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Agriculture has a long history in Georgia; it has led to a great variety of ancient crops. However, this diversity is under threat for many reasons. First, introduced crops have caused a loss of traditional cultivars, because the introduced crops are preferred due to their higher yield. Moreover, agricultural machines such as forage and grain combine harvesters imported to Georgia are constructed for widely distributed, imported crops and cannot be used to harvest local cultivars. Until recently, genetic erosion of ancient crop varieties was not a problem in the mountain areas of Georgia, which until the 1990s constituted a depository of local crop varieties of wheat, barley, rye, oat, common millet, traditional legumes, vegetables, herbs, and spice plants with specific varieties adapted to mountain conditions. These mountain areas worked as a depository because local mountain communities preserved their traditional ways of life and socioeconomic structures. Their traditional agricultural equipment, used on a large scale until the 1990s, still allows them to maintain areas under cultivation (with grain or other crops) on steep slopes and at high elevations where modern tractors cannot be used. Moreover, some old landraces of wheat and barley are still being used to prepare bread and beer for religious rituals. Currently, many endemic and native representatives of crop plants are in danger of extinction. International nature conservation institutions and Georgian scientific and nongovernmental organizations have developed plans to preserve the genetic resources of local cultivars.

Keywords: Agrobiodiversity; genetic erosion; germplasm conservation; Caucasus; Georgia.

Introduction

Agriculture in Georgia has a long history and is characterized by a great diversity of local landraces, varieties and even endemic species of cultivated plants. Many of them are adapted to mountain habitats and represent local high-mountainous landraces (Ketskhoveri 1957; Figure 1). Georgia is a mountainous country made up of two separate mountain systems: the Greater Caucasus Mountain Range, lying northwest to east-southeast between the Black Sea and Caspian Sea; and the Lesser Caucasus Mountains, which run parallel to the greater range, at a distance averaging about 100 km south. Two thirds of the country is mountainous, with an average elevation of 1200 m. The highest peaks are Mount Shkhara (5068 m) in the Western Greater Caucasus and Mount Didi Abuli (3301 m) in the Lesser Caucasus (Figure 2).

There are many threats to these oldest of crops in the modern period. In our opinion, the main threat to agrobiodiversity in Georgia is the loss of local and ancient crop varieties. These varieties are characterized by a high level of adaptation to local climatic conditions and often have high resistance to diseases. Protection measures in the country are still not being implemented at an appropriate rate. National policies and comprehensive measures are urgently needed to address the problem of conserving the genetic resources of ancient crops in Georgia.

Diversity of ancient crop varieties

The origin of ancient crop varieties and landraces in Georgia coincides with the period of their primary domestication (Vavilov 1987). Archeological data clearly show that the Caucasus, and particularly Georgia, was settled from prehistoric times, and agriculture was developed there during the Early Neolithic period (Javakhishvili 1930). The oldest archaeological findings of grape pips in the vicinity of village (v.) Shulaveri, southeast Georgia (Figure 2), are dated from approximately 6000 BC (Ramishvili 1988). Further archaeological evidence of prehistoric winemaking has been found very close to the Caucasian region, for example, in northern Iran at the Hajji Firuz Tepe site in the northern Zagros mountains, dating from circa 5400–5000 BC (McGovern 2003), and in the Levant and Jericho in the Near East, where archaeological findings date from circa 4000–3200 BC (Zohary and Spiegel-Roy 1975; Zohary and Hopf 2000). The great genetic and morphological variability of grapevines might be considered another indicator of the possible origin of the grapevine in the Caucasus. About 500 autochthonous grapevine varieties are known in Georgia (Javakhishvili 1930; Ketskhoveri et al 1960). These varieties are characterized by a wide range of color gamma and shapes of berries and pips; all these indicators hint at Georgia being an evolutionary center of origin (Vavilov 1931). Besides grapevines, other fruit trees such as pear, apple, cherry, cornel cherry, and plum have been domesticated from

FIGURE 1 Rye and barley fields in v. Ushguli (2140). (Photo by Maia Akhalkatsi)



local wild relatives of these crops (Vavilov 1931; Ketskhoveli 1957), representing primary gene pool species still to be found in the wild today (Akhalkatsi 2009).

Furthermore, wheat, barley, rye, oat, common millet, Italian millet, and legumes, including common vetch, pea, lentil, chickpea, alfalfa, and flax, and a number of herbal and spice plants, were already being cultivated in Georgia in the Eneolithic and Early Bronze periods (Javakhishvili 1930). Fourteen species of wheat, 144 varieties, and 150 forms were registered in Georgia by the 1950s (Menabde 1948). Sinskaya (1969) remarks that the Near East is the place of origin of 12 endemic wheat species (*Triticum boeoticum*,

Triticum monococcum, *Triticum durum*, *Triticum dicoccon*, *Triticum palaeo-colchicum*, *Triticum timopheevii*, *Triticum turgidum*, *Triticum carthlicum*, *Triticum polonicum*, *Triticum aestivum*, *Triticum macha*, *Triticum zhukovskiyi*), 8 of which originate from the South Caucasus, while 5 are endemic to Georgia: *T. monococcum*-gvatsa zanduri, *T. timopheevii*-chelta zanduri, *T. zhukovskiyi*-zanduri, *T. palaeo-colchicum*, and *T. macha* (Menabde 1948).

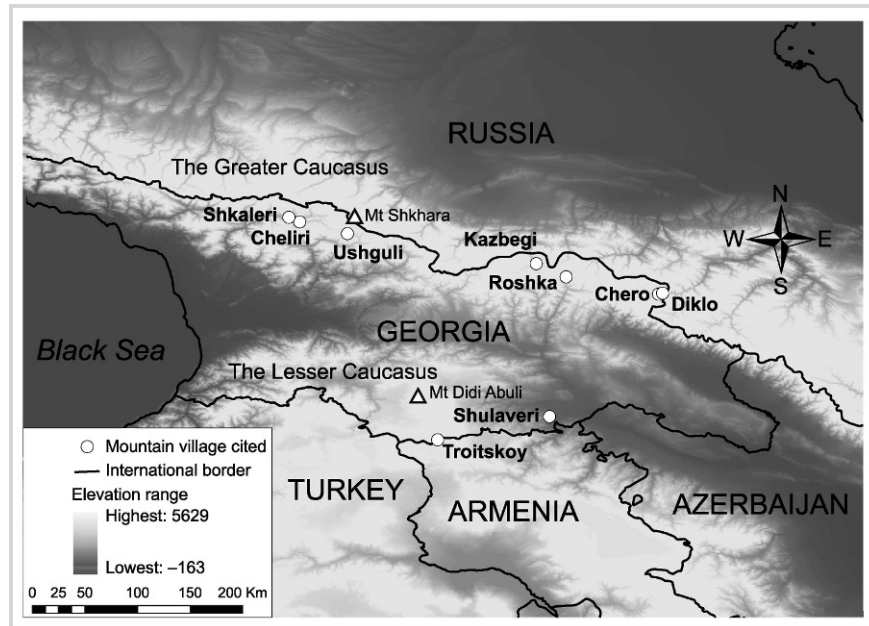
Processes leading to the erosion of crop genetic diversity

Introduced cultivated plants

Many cultivated plants have been introduced to Georgia from different

geographic regions since ancient times (Javakhishvili 1930). Some introduced crops have become very popular and widespread, such as cucumber (*Cucumis sativus*), eggplant (*Solanum melongena*), marigold (*Tagetes patula*), black pepper (*Piper nigrum*) introduced from India, and watermelon (*Citrullus lanatus*), which originated in South Africa. Maize (*Zea mays*), sunflower (*Helianthus annuus*), tomato (*Solanum lycopersicum*), bean (*Phaseolus vulgaris*), pepper (*Capsicum annuum*), and potato (*Solanum tuberosum*) were introduced in Georgia from America at about the same time as in Europe (Ketskhoveli 1957). Tea (*Camellia sinensis*) and citruses (*Citrus limon*, *Citrus reticulata*, *Citrus sinensis*) came from China in

FIGURE 2 Map of Georgia showing the geographical locations mentioned in the article. (Map by Maia Akhalkatsi)



the 1830s (Bakhtadze 1947). Georgia has become a secondary center of diversity for most of these crops: Bean, maize, potato, tomato, and cucumber landraces can be found in Georgia that do not exist in their countries of origin.

However, introduced crops have caused a loss of ancient cultivated plants: Italian millet has been completely replaced by maize, and bean has become almost the only legume cultivated in Georgia. There are several reasons for the genetic erosion of ancient cultivars and the wide distribution of new varieties of introduced crops. First of all, new cultivars have higher yields and are therefore preferred both as a source of food for local people and as a cash crop that determines local income. Another reason for loss of local cultivars (eg of Italian millet) is the development of technical equipment used for threshing cereals since the mid-20th century: Agricultural machines such as forage and grain combine harvesters imported by Georgia were only adapted to widely distributed crops. They could not be used for local cultivars, which were

suitable for production only with traditional technologies (Figure 3), as in the case of Italian millet cultivated on small peasant plots in the moist areas of Kolkhis.

This problem was particularly acute for lowland agricultural areas, where crops were cultivated in large amounts in *Kolkhozes*—agricultural farming corporations in Soviet times—where a list of cultivars for each agricultural region was even developed by the central governmental institutions in Moscow, and peasants had no choice regarding crops they could cultivate. The second half of the 20th century was also a period of intense selection work in breeding stations in the whole of the Soviet Union (eg, the highly productive awnless wheat cultivar *Bezustaja 1* developed in Russia has been sown in all wheat fields in Georgia since the 1970s). This variety eventually replaced Georgian endemic wheat species and traditional cultivars of ancient origin such as *Triticum aestivum* var. *erythrospermum*, *T. aestivum* var. *ferrugineum*, *T. aestivum* var. *lutescens*, *T. carthlicum*, *T. macha*, *T. palaeo-colchicum*,

T. timopheevii, and *T. zhukovskyi* (Berishvili 2001).

Disease and pollution events

In 1860, the *Vitis vinifera* was virtually wiped out in its places of its origin when an aphid, *Phylloxera vastatrix*, was accidentally introduced into France and within a few years had ravaged all the vineyards in Europe and the Caucasus, including Georgia (Ketskhoveli et al 1960). This aphid normally lives in the roots of certain American vines without doing any great harm, but once it gets into the root system of *V. vinifera*, it soon kills the plant. It was soon noticed that the few American vines found growing in Europe as exotics were not affected, and grafting quickly began. Currently, almost all Georgian grape varieties are grafted on rootstocks of American vines. This disaster made it necessary to undertake urgent steps for ex situ conservation of old, endangered and autochthonous grapevine varieties by establishing living collections in Georgia, something which was begun in the 1930s. To date, 929 varieties are protected in the living collections of

FIGURE 3 Salome Pakeliani standing next to a threshing sledge in v. Cheliri (1710 m). (Photo by Maia Akhalkatsi)



the State Agrarian University and the Georgian Scientific-Research Institute of Horticulture, Viticulture and Oenology (IHVO) in Mukhrani, Telavi, and Skra. Among these, 681 are products of selective work carried out in the 20th century, and only 248 are autochthonous Georgian cultivars remaining from the 524 known Georgian grapevine varieties (Maghradze et al 2009). Some ancient Georgian grape varieties can still be found on the private grounds of peasants and in several small living collections, such as in the grapevine collection of the G. Eliava National Museum in Martvili district, founded in 1972, which contains 24 old Kolkhic grapevine varieties (Eliava and Tsotsoria 2002).

Many new diseases have been introduced into Georgian agricultural fields in recent years, causing harm primarily to ancient cereals and vegetables. This was one more reason why local peasants began to prefer cultivating genetically modified (GM) plants and other new disease-resistant

varieties. However, the introduction of new parasites has revealed that endemic forms of Georgian crop plants contain valuable selective disease-resistant material for genetic engineering. The tetraploid and hexaploid endemic wheat species *T. timopheevii* and *T. zhukovskyi*, for example, are characterized by a high level of resistance to a new race (TTKS, commonly known as Ug99) and many other races of *Puccinia graminis* f. sp. *tritici* due to the wheat-stem rust resistance gene Sr36 (Tsilo et al 2007). *T. carthlicum* is characterized by immunity to diseases, a short growing period, and resistance to cold. In the past, this species was widespread in the high mountain areas of Georgia in the Samtskhe-Javakheti region (Berishvili 2001).

Air, water, and environmental pollution should not represent a big problem in Georgia, since industrial emissions are very low. However, according to our observations, in recent times, acid rain quite often falls in the high mountain villages of the Greater Caucasus. The polluted clouds

probably arrive from the industrial zones of south Russia, as suggested by local farmers in these regions.

Crop diversity in Georgia's mountain regions

Mountain areas as a depository of ancient crops

The process of genetic erosion of ancient crop varieties has not been a great concern for the mountain areas of Georgia, which until the 1990s acted as a depository of ancient crops (eg represented by mountain varieties of wheat, barley, rye, oat, common millet, traditional legumes, vegetables, herbs, and spice plants). The highest mountain villages in Georgia are v. Ushguli (2160 m) in Svaneti, Western Greater Caucasus; v. Roshka (2190 m) in Khevsureti, Central Greater Caucasus; v. Diklo and v. Chero (2160 m) in Tusheti, Eastern Greater Caucasus; and v. Troitskoye (2135 m) in Javakheti, the Lesser Caucasus (see Figure 2). Agricultural fields covered by cereals and vegetables commonly occur even

FIGURE 4 Highest registered wheat field in Georgia, in v. Chero (2160 m). (Photo by Maia Akhalkatsi)



in such high villages. Most varieties growing in mountain areas are local landraces and cultivars. Mountain landraces of rye (*Secale cereale*) and barley (*Hordeum vulgare* var. *nudum*, *H. vulgare* var. *pallidum*) reach their highest elevations in v. Ushguli (see Figure 1). The highest wheat field (*T. aestivum* var. *lutescens*) was discovered in 1986 by Georgian botanists in v. Chero at 2160 m (Figure 4).

One important consideration that explains why ancient cultivars were conserved longer in mountainous regions than in the lowlands is that the local population preserved their traditional ways of life and socioeconomic structures. The traditional agricultural system is characterized by dependence on local genetic resources and locally developed technologies. Even today,

peasants in mountain villages use an ox-drawn sledge made of wood for loading and transporting cereals (Figure 5) and a threshing sledge on threshing floors to thresh wheat, oats, rye, and barley (see Figure 3). Traditional agricultural equipment makes it possible to cultivate areas even on steep slopes and at high elevations, where modern tractors cannot be used. Moreover, some old

FIGURE 5 Ox-drawn sledge loaded with oats, v. Shkaleri (1307 m). (Photo by Maia Akhalkatsi)



landraces of wheat and barley are used to prepare bread and beer for religious rituals. Substitution of these landraces by others would go against centuries-old traditions.

Current threats to crop diversity in mountains

Despite these conditions that support the maintenance of ancient landraces, many endemic and native representatives of crop plants are currently in danger of extinction and face severe problems of genetic erosion in all mountainous regions of Georgia. While agrobiodiversity is declining rapidly in many areas of the world due to anthropogenic pressure (Körner et al 2007), including population growth, in Georgia the main reason for genetic erosion of ancient crop varieties is demographic decline in mountain regions due to harsh economic conditions and lack of modern infrastructure (Nakhutsrishvili et al 2009). The shift from ancient cultivars to modern high-yielding crops such as maize and potato, which took place in the lowland areas

much earlier, began in mountain villages only in the last 20 years. Greater income from marketing allows families to stay in mountain villages. Moreover, the economic security of the traditional farming systems in these mountain regions appears to be in jeopardy when traditional agriculture is replaced by cattle breeding, which causes abandonment of cultivated fields and their transformation into pastures.

National policy and an agenda for conservation of ancient crops

According to the National Biodiversity Action Plan of Georgia (Jorjadze 2005), national policies and comprehensive measures are urgently needed to address the problem of loss of crop genetic resources in Georgia. So far, international nature conservation institutions and Georgian scientific and nongovernmental organizations have taken care to preserve the genetic resources of local cultivars. Several gene banks and living

collections in Georgia maintain ex situ germplasm collections in research centers, such as the Institute of Horticulture, Viticulture and Oenology (IHVO), the Georgian Institute of Farming (GIF), the Institute of Tea and Subtropical Crops and Tea Industry (ITSCTI), the Tbilisi Botanical Garden and Institute of Botany (TBG&IB), and the Batumi Botanical Garden (BBG). Many seed banks worldwide contain about 7000 accessions of germplasm of Georgian cultivars and crop wild relatives (Bedoshvili 2008).

Another approach is to develop databases of existing and already extinct cultivars. Currently, great attention is being given worldwide to conservation and characterization of genetic resources of grapevine varieties, especially old, endangered, and autochthonous ones. The European Gene Banks (EURISCO) and European Union program GrapeGen06 are attempting to develop a database for all grape varieties, including those from Georgia. The main approach used today to identify the genetic diversity

of grapes is based on deoxyribonucleic acid (DNA) technology for detection of grape intracultivar variation (This et al 2006). A recently initiated project, “Mountain Biodiversity in the Caucasus and its Functional Significance,” supported by the Swiss National Science Foundation Program SCOPES, will build an electronic biodiversity archive for Georgia, and include data on mountain plant biodiversity in Georgia. Because it will be built in compliance with Global Biodiversity Information Facility (GBIF) standards, it will contribute to the Global Mountain Biodiversity Assessment (GMBA) mountain portal with GBIF (www.mountainbiodiversity.org). A research agenda concerned with the use of georeferenced mountain biodiversity data for science and management was developed at a GMBA workshop in Kazbegi, Central Caucasus, in July 2006 (Körner et al 2007). Such a database of the plant species of the Caucasus will become a prominent entry in the GBIF database and highlight the current status of plant genetic resources in Georgia.

In our opinion, establishment and maintenance of ex situ collections and databases is just a first step in the conservation process of ancient crop varieties. The next step should be return of conserved seed material to the fields of local farmers. From 2004 to 2009, the Global Environmental Facility/United Nations Development Fund (GEF/UNDP) project “Recovery, Conservation and Sustainable Use of Georgia’s Agro-Biodiversity” was carried out with the aim of conservation and sustainable use of threatened local plant genetic resources in the oldest historical mountainous region of Georgia, Samtskhe-Javakheti. This project enabled establishment of sources of primary seed and planting material for threatened crops and fruit varieties, and assisted farmers in accessing markets for organic products from such crops as lentil, grass pea, chickpea, faba bean,

common millet, Italian millet, etc. Another project was the return of the Georgian wheat variety Tseli Dolis Puri (*T. aestivum* var. *ferrugineum*) to the mountainous areas of Meskheti, where it was sown on 10 ha and produced bread that was introduced in shops featuring organic products in Tbilisi as of 2008. Afterward, this project was supported by the Georgian church, which expressed an interest in cultivating ancient crops on monastery grounds. However, these attempts have been realized only on a small scale and not in larger areas of the country.

Thus, an assessment of the effectiveness of current conservation strategies in conserving the diversity of ancient crops in Georgia reveals a gap in the reintroduction of conserved germplasm to the fields of local farmers. In our opinion, the corresponding governmental institutions responsible for conservation of biodiversity should refocus the strategy to require complementary in situ and ex situ conservation actions to maintain maximum diversity of the target taxon’s gene pool by supporting local farmers in reintroducing ancient crops on the market, thereby filling the gap.

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