Indian Journal of Traditional Knowledge
Vol 24(4), April 2025, pp 361-371
DOI: 10.56042/ijtk.v24i4.6854

# Agricultural transformations: early crop cultivation and farm animal domestication in South America, South Asia and India

A B Damania[a] & Preetam Joshi[b,*]

[a]Department of Plant Sciences, University of California, Davis CA 95616, USA
[b]Department of Biotechnology, Atmiya University, Yogidham Gurukul, Kalawad Road, Rajkot 360 005, Gujarat, India
*E-mail: preetam.joshi@atmiyauni.ac.in

*Received 18 July 2024; revised 16 February 2025; accepted 01 April 2025*

The emergence of agriculture, around 10,000-14,000 years ago, is of great significance in human history, captivating archaeo-botanists and ethnologists. This significant transition originated with the global cultivation of plants and the domestication of animals. Regions such as South Asia and the Andean territories became pivotal hubs for the development and diversification of agricultural crops. Excavations in these regions yielded valuable insights from examining ethnobotanical and animal remains, revealing a diverse range of ancient cultivated plant materials. Vedic literature suggests that the Indian Subcontinent may have been the earliest hub for crop domestication and civilization. Interestingly, South America embraced agriculture almost simultaneously with the initial farmers in the Middle East. The presence of certain crops in the Americas and the Indian Subcontinent prior to European contact suggests shared exchanges or independent parallel domestication. These findings illuminate early stages of crop and animal domestication, offering insights into the agricultural practices and civilizations of South America, South Asia, and India.

**Keywords:** Crop domestication, Early crop cultivation, Farm animal domestication, Independent parallel domestication, Vedic literature

**IPC Code:** Int Cl.[25]: A01G 22/00

Throughout the course of human evolution, humans have engaged in the domestication of plants and animals. This controlled cultivation and rearing of flora and fauna led to the emergence of agriculture, which served as a pivotal milestone in the development of civilizations. Various species of plants and animals have been independently domesticated across different regions and time periods. The precise origins of domestication, agriculture, and the establishment of civilizations in antiquity remain subjects of debate. For instance, Oak[1] utilized modern scientific tools and technology, complemented by Śāstrapramāṇam (proof as per the Vedic scripture of Hindu philosophy), to determine that the Indian civilization dates back approximately 25,000 years. This conclusion was drawn based on analysis of ancient literary works such as the epics Ramayana and Mahabharat. The Americas and the Indian Subcontinent are widely acknowledged as key regions where domestication began, serving as origins for numerous cultivated crops[2].

*Corresponding author

From an archaeological perspective, the earliest signs of domestication can be traced back to the Indian Subcontinent, around 10,000 to 14,000 years ago. The presence of settled agriculture utilizing both flora and fauna in the region eventually led to the development and flourishing of the Indus Valley Civilization approximately 5,000 years ago (3300-1300 BCE; with its mature period from 2600-1900 BCE). This was followed by the emergence of the Vedic Civilization (1500-500 BCE) and the Mahajanpada period (600-400 BCE), as supported by numerous archaeological findings throughout the Indian subcontinent. In contrast, evidence of crop cultivation in Mexico and South America appears between 7000 and 6000 BC, making it among the earliest instances of crop cultivation. Similarly, in eastern North America, although the first crops may be nearly as old, substantial evidence for their use only emerges between 3000 and 2000 BC. These agricultural developments led to the rise of various civilizations, such as the Caral Supe Civilization (3000-2500 BC), the Olmec Civilization (1200-400 BC), the Maya Civilization (500 BC-800 AD), the

Zapotec Civilization (500 BC-750 AD), the Nasca Civilization (1-700 AD), the Tiwanaku Empire (550-950 AD), and the Wari Civilization (750-1000 AD).

The course of domestication gave rise to the cultivation of rice in Asia and potatoes in South America, both of which were crucial crops during early civilizations. Beyond staple food crops, humans also cultivated plants for diverse uses-such as cotton for fibre and tulips for ornamental value. In the Old World, early efforts to domesticate animals emerged during the Mesolithic Period, but systematic domestication of species like goats and cattle began in the Neolithic Period, predating 9500 BCE. The Neolithic era marked the rise of organized agriculture and structured animal husbandry, with most key domesticated species being established during this time. However, some species followed much later timelines; rabbits, for example, were only domesticated in the Middle Ages, while sugar beet became a major crop for sugar production in the 19$^{th}$ century. Similarly, mint entered widespread cultivation in the 20$^{th}$ century, which also saw advancements in specialized animal breeding for premium fur production. The domestication of plants and animals differ between the Indian Subcontinent and South America during the early stages of agriculture. The domestication of plants and animals in these regions followed distinct paths due to variations in climate, available flora and fauna, and cultural practices. In the Indian Subcontinent, early agriculture was characterized by the domestication of crops such as wheat, barley, and pulses, as well as animals like cattle, buffalo, and sheep. In contrast, South America saw the cultivation of maize, potatoes, and quinoa, alongside the domestication of llamas and alpacas. The Indian Subcontinent's domestication was influenced by interactions with Mesopotamian civilizations, whereas South America's process remained largely independent, shaped by local environmental conditions[3]. A summary detailing the locations and approximate periods of domestication for selected crops and animals in the Americas and India can be found in Table 1.

The Russian geneticist Nicolai Vinovich Vavilov extensively studied and identified eight centers of crop origin and diversity, which encompassed the Americas and the Indian Subcontinent. In the Americas, the following centers were identified: 1) The South Mexican and Central American Centre: This region holds great significance for crops such as maize, Phaseolus beans, Cucurbitaceae species, as well as various other fruits, spices, and fiber plants. The papaya, believed to be native to the Southern Mexican tropics and neighboring Central America, has now spread to tropical and subtropical countries worldwide. 2) The South American Andes region: Comprising Bolivia, Peru, and Ecuador, this center is important for potatoes and other root crops, Andean grain crops, vegetables, spices, fruits, and substances like cocaine, quinine, and tobacco 3). The Chilean Centre: With only four species, including the potato, derived from the Andean region 4). The Brazilian-Paraguayan Centre: Known for crops such as *Arachis* (peanuts), Manihot (cassava), and Cashew, which have significant economic importance. However, it should be noted that for some crops like Cashew, there is speculation about the existence of parallel centers of origin based on archaeological evidence[4]. Other crops such as pineapple, *Hevea* rubber, and *Theobroma cacao* were likely domesticated at a later period[5]. Among the primary centers of crop domestication, Vavilov designated the South Asian region, particularly India, as a key area of agricultural origin[6]. This center was so vast that Vavilov further divided it into two subcenters: a) Indo-Burma: Primarily including Assam, Bangladesh, and Burma, as well as the Indus Valley and Gangetic plains, with a total of 117 crop plants. b) Siam-Malaya-Java: The Indo-Malayan Centre encompassing Indo-China and the Malay Archipelago, with 55 crop plants. Table 2 provides a list of some important cultivated plants from these centers of origin, as described by Nikolai Vavilov[6].

Table 1 — Location and starting period of domestication of selected crop and animals around the world (Source: Simmons, 1989[30]; Allchin and Allchin, 1997[31])

| Location | Starting period | Domesticated Plants and Animals |
|---|---|---|
| Indian subcontinent | 9000 BC | Rice, Pigeon pea, Eggplant, Jujube, Sheep, Goat (Water Buffalo: ~2500 BC) |
| Ayacucho - Peru | 6000 BC | Lima Bean, Common Bean |
| Tehuacan - Central Mexico | 6000 BC | Maize, Squash, Gourds (Maize cultivation intensified: ~5000 BC) |
| Ocampo Cave North-Eastern Mexico | 7000 BC | Squash, Gourd, Scarlet Runner Bean (Common Bean domesticated later: ~4000 BC) |
| Highland South America | 2000 BC | Guinea Pig (Llama & Alpaca domesticated: ~1500 BC) |

Table 2 — American and Indian centers of origin of crop plants of the eight world centers described by Nikolai Vavilov (1992)[6]

| Center | Area or Location | Plants |
|---|---|---|
| 1) South Mexican and Central American Center | Includes southern sections of Mexico, Guatemala, Honduras and Costa Rica. | Maize, Malabar Gourd, Lima Bean, Tepary Bean, Jack Bean, Grain Amaranth, Winter Pumpkin, Upland Cotton, Common Bean, Bourbon Cotton, Henequen (Sisal), Sweet Potato Pepper, Papaya, Cashew, Wild Black Cherry, Guava, Cherry, Tomato |
| 2) South American Center (62 plants listed: three subcenters) | 2A) Peruvian, Ecuadorean, Bolivian Center: | Andean Potato and other Endemic Cultivated Potato Species, Lima Bean, Starchy Maize, Tobacco, Common Bean, Edible Canna, Potato, Pumpkin, Pepper, Egyptian Cotton, Cocoa, Tomato, Guava |
| | 2B) Chiloe Center (Archipelago near the coast of southern Chile) | Common Potato (48 Chromosomes), Chilean Strawberry |
| | 2C) Brazilian-Paraguayan Center | Manioc, Rubber Tree, Peanut, Pineapple, Brazil Nut, Cashew |
| 7) Indian Center Two subcenters | 7A) Indo-Burma: Main Center (India): Includes predominantly Assam, Bangladesh, Gangetic plains, and Burma (117 plants) | Little millet, Urd Bean, Mung Bean, Cowpea, Eggplant, Cucumber, ridge gourd and smooth gourd Radish, Mango, Sugar Cane, Tamarind, Sesame, Tree Cotton, Oriental Cotton, Jute, Rice, Rice Bean, Bamboo, Pigeon Pea, Taro, Hemp, Cinnamon Tree, Croton, Coconut Palm, Turmeric, Indigo, Black Pepper, |
| | 7B) Siam-Malaya-Java: Indo-Malayan Center: Includes Indochina and the Malay Archipelago, (55 plants) | Pummelo, Velvet Bean, Coconut Palm, Clove, Black Pepper, Banana, Sugarcane, Manila Hemp |

**South America**

Archaeological research led by Vanderbilt University anthropologist Tom Dillehay in Peru's Nanchoc Valley uncovered evidence of early agricultural development[5]. Excavations revealed 7,600-year-old peanut remains and 5,500-year-old cotton fragments preserved in ancient hearths and floor deposits. According to Dillehay's team, the Nanchoc people's adoption of farming practices triggered profound societal transformations. These innovations ultimately fostered agricultural intensification, the development of governance systems, and the growth of settlements in both highland and coastal Andean regions between 4,000-5,500 years ago[7]. Significantly, botanical analysis showed these crops were not indigenous to the area, suggesting introduction through trade networks or migrating cultivators. The sites also yielded additional domesticated species including pseudo-cereals resembling quinoa, manioc, various tubers, and fruits, found in cultivated plots accompanied by irrigation features and farming implements. Earlier research published in Science indicates squash (*Cucurbita* spp.) cultivation in Peru dates back approximately 10,000 years[8].

Due to a limited number of actual specimens, archeo-botanists have heavily relied on written records and linguistic evidence in their study. However, it should be noted that the writings of ancient Greek philosophers, including Socrates, Theophrastus, and Plato, regarding domesticated plants and animals were not always entirely accurate. Upon the arrival of the first humans in the Americas, they discovered that the large fauna in the region was easy to hunt. Consequently, many potential draft animals became extinct due to overhunting. As a result, for the next thousand years, civilizations in the Americas had to develop without the use of draft animals. The primary animals domesticated for transportation and labor in South American agriculture were the horse, mule, donkey, and llama. These animals served this purpose for over a thousand years in various areas, until mechanical tools and machines eventually replaced them. It is currently believed that the majority of South American farm animals originated from outside the continent. Only two cultures in pre-Columbian Americas employed domesticated animals for load-bearing work; the Inca Civilization (Andes Mountains, 13$^{th}$-16$^{th}$ century CE) and The Aztec Civilization (Mesoamerica, 14$^{th}$-16$^{th}$ century CE). The Andean communities were among the few who domesticated llamas for similar purposes. The mountainous terrain of the region was not well-suited for wheeled transportation and traditional farming practices. However, further archaeological and ethnobotanical research is necessary in South America to gain a clearer understanding of farm animal and crop domestication.

It is possible that farming in South America began earlier than what is currently mentioned in existing literature. Among the four domesticated *lamoid* species, namely *alpacas* and *llamas*, the other two species-*vicuña* and *guanaco*-remain as their wild counterparts.

Located approximately 600 km north of Lima (situated on the arid Pacific coast, near the foothills of the Andes), an impressive earthen mound commands attention as it overlooks the sea. Known as Huaca Prieta, this ceremonial structure was constructed around 7800 years ago. Recent archaeological investigations at Huaca Prieta have uncovered groundbreaking evidence buried 30 m beneath its massive earthen structure. The discovery includes an assemblage of lithic tools, faunal remains, and botanical materials deposited approximately 15,000 years ago by pioneering South American populations. This extraordinary discovery establishes Huaca Prieta among the continent's oldest documented occupation sites, offering critical insights into early human migration patterns. The evidence suggests that Pleistocene-era settlers may have advanced at a markedly gradual pace along Pacific coastal corridors, challenging previous assumptions about the speed of peopling in the Americas. The revelation of early human habitation left archaeologist Tom Dillehay, who led the study at Vanderbilt University in Nashville, astounded. Originally focused on investigating the mound itself, Dillehay's team of geologists expressed a desire to examine the landform beneath it. After five years of meticulous excavation, they reached a depth of 31 m, where they made a shocking discovery. The deep layers harbored unmistakable traces of human presence, confirmed by radiocarbon dating to date back 15,000 years before the present time[8].

The significance of Huaca Prieta has led certain researchers to advocate for its inclusion in the expanding collection of sites predating 14,000 years ago, which have drastically reshaped the understanding of early South American civilizations. Traditional migration models proposed that Pleistocene hunter-gatherers entered the Americas *via* Beringia before moving southward through an ice-free corridor along the eastern Rocky Mountains, reaching the continental interior approximately 13,000 years ago. However, the discovery of pre-Clovis sites like Monte Verde in Chile (radiocarbon dated to ~14,500 BP) has fundamentally altered this paradigm. This archaeological evidence demonstrates that human populations had already colonized southern South America by the late Pleistocene, necessitating earlier migration timelines and potentially alternative coastal routes. This suggests that these early settlers must have traversed Canada prior to the existence of an ice-free corridor, leading to the deduction that their most probable entry route into the Americas was along the Pacific coast. However, concrete evidence directly supporting this migration hypothesis remains absent.

Peruvian wild potato tubers exhibit a uniformly bitter taste and contain potentially hazardous levels of diverse steroidal alkaloids. The initial phase in the evolutionary progression of this significant tuber crop likely involved the selection of less bitter clones during the gathering stage. It is estimated that between 4000 and 7000 years ago, alkaloid-free diploids emerged, completely devoid of the bitter taste. Subsequently, a considerable range of variations in skin color, flesh color, and shape began to manifest. The region where domestication took place and the original habitat of the potato is presumed to be the high plateau of Bolivia-Peru and the surrounding vicinity of Lake Titicaca, where both wild and cultivated diploids still persist. For instance, Sir John Malcolm introduced potatoes to Persia in 1815 while serving as a minister in the supreme court of Persia, appointed by the government of India (British East India Company). During his second mission to Persia in 1808, Sir John personally identified suitable land for potato cultivation, as reported in his book "The History of Persia: From the Earliest Period to the Present Time." He observed that the soil in numerous areas proved highly conducive to potato cultivation[9].

While the ancient states of South America originated under varying environmental conditions and diverse historical contexts, there was a common characteristic among the Inca, Maya, and Aztec states. They all thrived on robust and productive agricultural economies that relied on staple crops such as squash (*Cucurbit* spp.), beans (*Phaseolus* spp.), and maize (*Zea mays*). Additionally, within the expansive tropical lowlands of South America, indigenous communities successfully cultivated several other plants, including manioc (*Manihot esculenta*) and sweet potato (*Ipomoea batatas*).

Quinoa (*Chenopodium quinoa*) is currently cultivated in a region extending southward from

Colombia along the Andes, at elevations exceeding 1800 m. This cultivation zone encompasses Peru and Bolivia, reaching into Chile and Argentina. *C. carnosulum*, a widely distributed wild chenopod in Peru, is considered the most probable wild ancestor of quinoa. An excavation led by John Rick from Stanford University uncovered the Panaulauca cave, which overlooks the Junin basin at an altitude of 4150 m. Located 150 km northeast of Lima, this cave is of significant archaeological interest. Notably, the Junin Basin has also provided evidence indicating the domestication of llamas (pack animals of the camel family) approximately 5000 to 4000 years ago. Consequently, some researchers have suggested a hypothesis that quinoa and llamas were domesticated concurrently. Llamas show a particular fondness for both wild and cultivated quinoa varieties.

In 1996, Kent Flannery conducted an excavation of the Guilá Naquitz Cave in Oaxaca, Mexico, and subsequently published a report. The report encompasses valuable insights into the transition from a hunter-gatherer lifestyle to agriculture. The hunter-gatherers in this region roasted maguey, consumed cactus fruits, extracted syrups from mesquite pods, and incorporated wild onion and wild bean flowers into their culinary practices[10].

A recent article published in the New York Times presented findings that debunked the long-standing belief that women were primarily gatherers while men were hunters. The report presents significant archaeological evidence from the Andean highlands of Peru, where researchers excavated a 9,000-year-old female burial associated with a specialized toolkit for hunting megafauna. This discovery challenges conventional assumptions about gender roles in early hunter-gatherer societies, suggesting women may have actively participated in big-game hunting activities during the Early Holocene period. This groundbreaking discovery challenges the widely accepted notion that ancient hunter-gatherer societies strictly adhered to gender roles, with men hunting and women gathering. The hunting kit found with the female skeleton contained tools and artifacts specifically associated with big-game hunting, such as those used for pursuing vicuña and deer[11]. A research team led by archaeologist Randy Haas (University of California, Davis) documented these findings in Science Advances, presenting osteological and artefactual evidence that the young woman was an active participant in big-game hunting. Their analysis suggests she regularly engaged in hunting expeditions targeting vicuña (*Vicugna vicugna*) and deer (*Cervidae* spp.), which served as staple protein sources for her community. This discovery provides empirical support for reconsidering gender-based labour divisions in prehistoric hunter-gatherer societies[12].

The discovery of a female hunter was an uncommon occurrence, prompting to make a broader assertion regarding the division of labor during that particular era in the Americas[12]. Their argument is supported by further research, which indicates a significant level of participation in hunting by both genders. As a whole, their conclusion states that "early females in the Americas engaged in big game hunting."

At an elevation of nearly 13,000 feet in the Puno district of southern Peru, Haas and other researchers made a significant discovery at a site known as Wilamaya Patjxa[12]. This find included the burial site of a young female accompanied by hunting materials. The initial uncovering of artifacts in this area near the community of Mulla Fasiri took place in 2013, thanks to the efforts of a local collaborator named A. Pilco Quispe. Subsequently, Haas collaborated with community members and conducted an excavation covering an approximate area of 400 square feet, resulting in the recovery of approximately 20,000 artifacts[12]. Among the findings were five burial sites containing the remains of six individuals, one of whom was the female hunter.

The indigenous peoples of the Americas possessed remarkable expertise not only in detoxifying food but also in actively seeking out plants with psychoactive properties, including cocaine (*Erythroxylum* spp.). Additionally, they possessed extensive knowledge of medicinal plants, utilizing them for wound healing and disease treatment. The Aztec civilization, in particular, had a rich pharmacopeia of medicinal remedies that were likely on par, if not superior, to the medicines available in Europe during the era of Spanish conquests. Unfortunately, the swift destruction of indigenous culture and the associated indigenous technological knowledge (ITK) prevented in-depth study and documentation. Regrettably, the loss of ITK has continued unabated. Some surviving American Indian tribes, particularly those in tropical South America, still utilize various plant species that remain largely unknown to modern science.

**South Asia**

South Asia, specifically India, stands as one of the twelve major centers/regions of crop plant diversity worldwide. India occupies a strategic geographic position between 8°4' to 37°6' north latitude and 68°7' to 97°25' east longitude, exhibiting remarkable topographical diversity from coastal plains to Himalayan peaks exceeding 4,500 m elevation. The subcontinent's climate regimes demonstrate exceptional variability, featuring: (a) Tropical monsoon systems dominating peninsular India; (b) Temperate to alpine zones in the northwestern Himalayas; (c) Arid to semi-arid ecoregions across the Thar Desert and northwestern plains. This complex bioclimatic gradient supports one of the world's most biodiverse terrestrial ecosystems, with vegetation types ranging from tropical evergreen forests to alpine meadows. Floristically, India boasts an extraordinary richness, harboring 17,926 species belonging to 2,991 genera and 251 families, which accounts for roughly 7% of the world's described species[13]. Approximately 5,725 species are endemic to India, constituting 33.5% of the country's flora, and this number has increased to 6,000 according to recent surveys[14]. The Himalayas alone house 3,471 of these endemic species, followed by 2,051 species confined to the peninsular region and approximately 239 species found in the Andaman and Nicobar Islands[15]. The northeastern region of India is estimated to possess the highest floristic richness, harboring over 50% of the country's total species diversity, including around 7,000 species, with 700 orchid species alone[16]. Such botanical diversity renders the Indian region both unique and captivating. Based on the distribution of flora and fauna, the Indian subcontinent has been classified into ten widely recognized biogeographical regions, which have recently expanded to eleven with the division of the Deccan Peninsula into the Indian peninsula and the Eastern Ghats[17]. These sub-regions are as follows: Trans Himalayas, Himalayas, Northeast, Gangetic plain, Arid Zone, Semi-arid Zone, Eastern Ghats, Peninsular India, Western Ghats, Coastal region, and Island region. Furthermore, the Indian Council of Agricultural Research (ICAR) has identified eight agro-climatic regions based on physiographic, climatic, and cultural factors[18], which have been further refined to include 21 micro-climatic regions[19].

According to the latest survey, Indian agriculture cultivates 811 plant species and encompasses more than 900 wild relatives of cultivated plant species, distributed across 10 (+1) biogeographic regions within the country. These numbers are notably higher than what is commonly reported in existing literature. Additionally, the survey shed light on the crucial role played by Indian communities in the domestication and cultivation of approximately 215 economically significant plant species. Moreover, around 600 exotic crop species from various parts of the world have been successfully adapted to Indian conditions[20]. Throughout history, multiple influences have contributed to the introduction of new crops in India.The agricultural biodiversity of South Asia was profoundly reshaped through successive waves of crop introductions during the medieval and colonial periods. The Mughal Empire and Iberian colonizers (Spanish and Portuguese) facilitated the transfer of crucial temperate and tropical species between the 16$^{th}$-17$^{th}$ centuries, including orchard crops like pears (*Pyrus* spp.) and grapes (*Vitis vinifera*), New World domesticates such as maize (*Zea mays*), potatoes (*Solanum tuberosum*), and tomatoes (*Solanum Lycopersicon*), along with cash crops like opium poppy (*Papaver somniferum*). Earlier Arab trade networks had already established key spices in the region, notably clove (*Syzygium aromaticum*), coriander (*Coriandrum sativum*), and fennel (*Foeniculum vulgare*), which became integral to South Asian cuisine. British colonial administration later systematized agricultural exchanges during the 18$^{th}$-19$^{th}$ centuries, introducing globally valued commodities including coffee (*Coffea arabica*), cocoa (*Theobroma cacao*), and tea (*Camellia sinensis*), the latter becoming a dominant plantation crop in Assam and neighbouring regions. This period also saw the introduction of subtropical fruits like litchi (*Litchi chinensis*) and strawberry (*Fragaria × ananassa*), as well as medicinal species such as cinchona (*Cinchona* spp.), the source of quinine. These layered agricultural introductions created a complex mosaic of cultivation systems that continue to define the region's agroeconomic today.

*Cinchona officinalis*, also known as quinine bark, is a famous plant from the rainforest and a significant discovery. Legend has it that the name "cinchona" originated from the countess of Chinchon, the wife of a Peruvian viceroy, who was cured of a malarial fever using the bark of the cinchona tree in 1638. Furthermore, the Portuguese established their presence in India in 1505, with a missionary thought to have brought the cashew nut to western India from Brazil, although evidence suggests its ancient presence in both South America and India, possibly indicating parallel domestication or early contact between the two regions. Another intriguing plant, *Abrus precatorius* L., commonly known as jequirity bean, has been valued for its medicinal, economic, and ornamental properties since ancient times. Mentions of this plant in Hindu literature predates 600 BC, indicating its origin in India or Southeast Asia[21].

The existing diversity matrix comprises the gene pool of indigenous crop plants, along with their wild and/or weedy relatives, as well as well-adapted introductions from various regions worldwide. The introduced varieties, depending on factors like introduction time, extent of material brought, and areas of introduction, have significantly contributed to the vast accumulation of diversity within the Indian subcontinent. Notable examples include cereals like *Triticum aestivum* (wheat), *Hordeum vulgare* (barley), *Avena sativa* (oats), and *Zea mays* (maize); pulses such as *Cicer arietinum* (gram), *Phaseolus vulgaris* (French bean/rajmah), and *Pisum sativum* (peas); vegetables like *Solanum tuberosum* (potato), *Allium cepa* (onion), *Brassica oleracea* varieties (cauliflower, cabbage), *Daucus carota* (carrot), and *Solanum lycopersicum* (tomato); fruits such as *Malus domestica* (apple), *Pyrus communis* (pear), *Vitis vinifera* (grapes), *Prunus avium* (cherry), *Prunus persica* (peach), and *Prunus armeniaca* (apricot); oilseeds like *Glycine max* (soybean), *Helianthus annuus* (sunflower), and *Arachis hypogaea* (groundnut), alongside fibre crops like *Gossypium* spp. (cotton). Additionally, there have been limited instances of diversity enhancement in medicinal plants like mint, liquorice (*Glycyrrhiza glabra*), *Digitalis* (foxglove), *Cinchona* (quinine), *Hyoscyamus* (henbane), and others like *Humulus lupulus* (hops).

Singh and Nigam provide compelling evidence, derived from archaeobotanical remains, sculptural depictions, and references in ancient Indian literature (Sanskrit), indicating the introduction of approximately 65 crop species into India prior to the 8th century[22]. Remarkably, these species include crops originating from the Americas as well. The ancient presence or introduction of these species in India can be attributed to various factors such as geological and geographical fragmentation of continental landmasses, subsequent drift, natural or human-induced transoceanic migrations and movements, as well as trade and cultural exchanges.

**Discussion**

The process of domestication, which involved the cultivation of plants and the raising of animals, is widely believed to have commenced globally around 12,000-11,000 years ago, coinciding with the conclusion of the last ice age. This notion, although subject to debate, is supported by the consensus among scholars. Domestication, being a multifaceted process, encompassed various interactions between humans, plants, and animals, often spanning extended periods. Ecological, biological, and cultural factors all played significant roles in driving this process. Throughout history, civilizations commonly settled along rivers, and this trend extended to other regions as well[23]. For instance, in South America and South Asia, settlements were typically located near rivers, lakes, marshes, highlands, and coastlines. These areas provided fertile and moist soils that facilitated successful agricultural endeavors, resulting in abundant and dependable harvests. While this pattern indicates a global convergence, the diverse instances of domestication across different crops suggest the existence of multiple cultural agricultural origins. Notably, examples exist where parallel domestication of crops seemingly occurred independently in South America and South Asia, specifically India. One such example is the domestication of cotton. Pre-Columbian peoples of the Yucatan peninsula likely first domesticated cotton in South America. From there, the domesticated cotton varieties spread throughout Mesoamerica, northern South America, and the Caribbean basin between 3400-2300 BC. Similarly, cotton has been cultivated, spun, and woven in the Indus Valley of the Indian Subcontinent since 3000 BC, as documented by Gulati[24]. During this period, inhabitants of the Nile valley in Egypt also wore cotton garments. Arabs introduced cotton to Europe around 800 AD. Another interesting case is the domestication of the cashew nut, which is believed to have occurred in the northern parts of South America, the Caribbean, or southern Mexico. Portuguese explorers introduced the cashew nut crop to the East Indies, Africa, and India in the sixteenth century. However, Singh challenges this hypothesis based on ancient writings and sculptures, suggesting that cashew was present in India much earlier than previously reported[4]. Singh proposes that its systematic introduction and domestication in India likely occurred through voyages along the eastern African coast, involving interactions with the

Americas in prehistoric times. Environmental factors significantly influenced the agricultural choices of early farmers. In the Indian Subcontinent, the monsoon system determined crop cycles, while river valleys like those of the Indus provided fertile soil. In South America, the varied topography led to the adaptation of terrace farming in the Andes and floodplain cultivation in the Amazon basin. The need to adapt to diverse climates led to innovative agricultural techniques in both regions[25].

The global movement of people and goods throughout history allowed crops and animals to spread between different regions. Plants from the Americas like corn, potatoes, tomatoes, and hot peppers became important worldwide. At the same time, crops such as rice, wheat, and sugar cane from Europe and Asia became widely grown in the Americas. This exchange of plants and animals helped increase food supplies and supported growing populations in many parts of the world[26]. A notable example is the cultivation of potatoes, which was limited to South America until the 14th century. Traders played a crucial role in introducing potatoes to Europe and India, ultimately establishing them as important crops in both regions by the 18th century. Similarly, maize and cassava were brought to Africa by the Portuguese in the 16th century, eventually replacing sorghum and millet as the primary food crops of Africa. In contrast, rice originated in Southeast Asia and West Africa and became popular in the New World by the late 15th century. Through the sharing of knowledge and skills by enslaved Africans, Europeans began large-scale cultivation of rice, making it a staple food. Additionally, coffee was introduced to the Americas from Africa and the Middle East, while sugarcane was introduced from the Indian Subcontinent. The simultaneous emergence of agriculture in South America and the Middle East played a crucial role in the rise of civilizations. In the Middle East, surplus food production led to urbanization, social stratification, and complex political structures, such as those seen in Mesopotamia. Similarly, in South America, civilizations like the Norte Chico and later the Inca developed irrigation systems, social hierarchies, and trade networks based on agricultural productivity[27].

One of the distinctive features of the evolution of ancient Indian agriculture, in comparison to South American agriculture, is its integration with social and religious beliefs, which were manifested in various agricultural practices[28]. Shared exchanges, such as the spread of crops along trade routes, contributed to genetic diversity by introducing new varieties and hybridization. However, independent domestication also led to unique genetic traits suited to local environments. For example, rice varieties in India evolved differently from maize varieties in South America due to distinct evolutionary pressures. This parallel development highlights the role of human selection in shaping agricultural biodiversity[29]. In this context, nature, including forests, plants, and animals, was equated with deities and revered as vital components essential for human survival. Saints and teachers dedicated their efforts to studying and documenting the properties and cultivation methods of plants and animals, resulting in early writings such as the Vedas. These ancient agricultural texts, which began with the Rigveda and were estimated by Oak to date back as far as 22,000 BCE to the 6th millennium BCE, have benefited Indian agriculture across generations[1,28]. Table 3 presents some available records depicting ancient Indian agricultural practices.

Table 3 — List of available documents about Indian agriculture during ancient period (Giri and Hedayetullah, 2020)[32]

| Document/Literature | Period | Essential information mentioned associated with agriculture |
|---|---|---|
| *Rigveda* | (c.3700 BC) | Soil, land and village settlement; Manure and manuring; Crop husbandry inclusive of plant protection measures, agricultural technology and agricultural implements; Irrigation system; Animal husbandry and Meteorological observations in relation to crop prospects |
| *Atharvaveda* | (c. 2000 BC) | Manuring of Yava (barley) seeds with clarified butter and honey as pre-sowing treatments of seeds; preventive and remedial measures of Borer (tarda), noxious insect (upakvasa) and locust (patanga), hooked insect (samanka), Rodents (vyadvaras) and rats (akhu); Weed control was also recommended by burying of several plant substances in the fields before sowing of seeds |
| *Ramayana*<br>*Mahabharata* | (c.2000 BC)<br>(c.1400 BC) | Information about different rivers and its branches and their role in agriculture |
| *Krishi-Parashara* | (c.400 BC) | Details of the design of the plow with Sanskrit names for different parts. disc plow, seed drill, blade harrow (bakhar), wooden spike tooth harrow, plankers, axe, hoe, sickle, supa for winnowing and a vessel to measure grain (udara); two-wheeled bullock carts for transportation, grainery (storage); astrological models for predicting rains in a particular season; method of preparing manure from cow dung; description of a cattle shed; Methods to protect cattle from diseases. |

Moreover, the Indian subcontinent boasts an extensive corpus of systematized ancient literature documenting agricultural and botanical knowledge. Among the most significant works are Kautilya's Arthaśāstra (circa 300 BCE) addressing statecraft and resource management, Amara-siṃha's Amarakośa (approximately 200 BCE) serving as a foundational Sanskrit lexicon, and Patañjali's Mahābhāṣya (similarly dated to 200 BCE) containing linguistic observations. The Tamil Sangam literature (200 BCE-100 CE) represents early Dravidian literary traditions. Later contributions include Vārāhamihira's BṛhatSaṃhitā (c. 500 CE) encompassing astrological and agricultural knowledge, Kāśyapīyakṛṣisūkti (c. 800 CE) focusing on agrarian practices, and Surapāla's Vṛkṣāyurveda (c. 1000 CE) detailing arboriculture. Medieval compilations such as Cāvuṇḍarāya's Lokopakāra (1025 CE), Someśvara's Mānasollāsa (1131 CE) covering royal horticulture, Sāraṅgadhara's Upavanavinoda (c. 1300 CE) on garden management, and Bhāvamiśra's Bhāvaprakāśa Nighaṇṭu (c. 1500 CE) documenting medicinal plants collectively constitute a comprehensive phytological tradition.These extensive and well-documented sources have facilitated gradual improvements and refinements in Indian agricultural techniques, and they now serve as valuable contributions to the world's collective heritage[32].

## Conclusion

The process of domestication, involving the cultivation of plants and the rearing of animals, took place in various regions worldwide, including the Americas and the Indian Subcontinent. Over the course of millennia, the continuous cultivation and rearing of these species led to the evolution and advancement of agriculture, as well as the development of diverse civilizations across different parts of the globe. Many of these civilizations emerged along the banks of rivers and in valleys nestled within mountains. These areas provided ideal conditions for sustainable cultivation, animal husbandry, and human settlements, as they offered rich, moist, and fertile soils that ensured abundant and reliable harvests. In South and Central America, as well as in the Indian Subcontinent, settlements thrived near lakes, marshes, or rivers, capitalizing on the favorable environments for agriculture. Vavilov identified these regions as centers of crop origin and diversity, where agriculture independently developed through the domestication of various crops. Today, these crops have achieved global significance, serving as essential sources of food and nutrition.

In contrast to the early farmers in the Old World, the agricultural practices in the New World did not involve the domestication of farm animals. Even in Peru, where llamas and alpacas were present, these animals were primarily utilized as pack animals, and in the case of alpacas, for their wool and meat as well. Interestingly, the ancient farmers of Central America lacked iron tools and did not possess plows. Instead, their tools were predominantly made from wood, stone, and bone. In a similar vein, the early generations in the Indian Subcontinent documented comprehensive information about agricultural plants and animals, including their characteristics, properties, and optimal cultivation and rearing methods. This knowledge and documentation have contributed to the sustained survival of agricultural practices in the region over millennia and centuries, despite various challenges. In contrast, many American civilizations faced significant decline and near-extinction, resulting in the loss of valuable agricultural knowledge.

Although there might have been shared factors in the regions where agriculture and farming originated, these similarities did not extend too far. However, the presence of common crops in ancient times between the two continents does indicate some level of connection. While examining the distinct and extensive histories of these regions and attempting to identify a singular set of shared characteristics, it is crucial not to overlook the abundant diversity that exists among the various centers of agricultural development. While humanity as a whole possesses greater knowledge in the realms of science and art compared to the early agriculturists and farmers, it is important to acknowledge that ancient foragers and gatherers displayed remarkable innovation, skill, and knowledge on an individual level.

The study of early agriculture supports the idea that agricultural surplus was a key driver of social complexity, supporting theories that link food production to urbanization and state formation. However, findings also challenge linear models of development, as some early farming societies did not immediately transition into hierarchical states. This suggests that agriculture’s impact varied based on cultural and environmental contexts. Ancient agricultural practices offer valuable insights for modern sustainability. Techniques such as crop rotation, organic fertilization, and water conservation, used by early farmers, align with contemporary sustainable farming practices. Understanding ancient resilience strategies can help address modern challenges like soil degradation, climate change, and food security.

## Acknowledgements

The authors express their gratitude to Prof. Anurudh K. Singh, Former Head, Germplasm Conservation Division, National Bureau of Plant Genetic Resources (ICAR), Pusa Campus, New Delhi, for his invaluable contribution in critically reviewing and providing valuable suggestions for the manuscript.

## Conflict of Interest

The authors declare that there are no conflicts of interest.

## Author Contributions

AB conceptualized the idea, conducted the research, and wrote the article. P performed the literature survey, provided valuable insights into historical uncertainties, and contributed to the writing and editing of the manuscript.

## Ethics Approval

Since this article examines the historical phenomenon of agricultural expansion and the domestication of farm animals in South America, South Asia, and India, it is important to note that it does not generate any economic gain or cause harm to the territories or their residents. Consequently, there is no potential for ethical standards to be violated in this research, as its sole purpose is the study of historical facts.

## Data Availability

The data used in this study is derived from publicly available sources, as cited in the manuscript. No new datasets were generated or analyzed specifically for this study. For any additional information, the authors can be contacted.

## References

1 Oak N N, 12209 BCE Rama Ravana Yuddha, (Subbu Publication, Hubli, India), (2018) p. 112.

2 Vavilov N I & Dorofeev V F, Origin and geography of cultivated plants, (Cambridge University Press, UK), (1992) 92-101.

3 Gupta A K, Origin of agriculture and domestication of plants and animals linked to early Holocene climate amelioration, *Curr Sci*, 87 (1) (2004) 54-59.

4 Singh A K, Early history of crop presence/introduction in India: III, *Anacardium occidentale* L., cashew nut, *Asian Agri-History*, 22 (3) (2018) 197-202.

5 Hawkes J G, Back to Vavilov: Why were plants domesticated in some areas and not in others?, In: The Origins of Agriculture and Crop Domestication – The Harlan Symposium, (A. B. Damania *et al*.), (ICARDA, Aleppo, Syria), (1998) p. 5-8.

6 Vavilov N I, Centres of Origin of Cultivated Plants, *Bull Appl Bot Genet Plant Breed*, 16 (2) (1926) 139-248.

7 Dillehay T D, *The settlement of Americas: A new prehistory*, (Basic Books, New York, USA), (2008) p. 372.

8 Wade L, Traces of some of South America's earliest people found under ancient dirt pyramid, *Science*, May 24, 2017.

9 Rahemi A, A Chronicle of introduction of potato to Persia, *Asian Agri-History*, 24 (1) (2020) 75-80.

10 Harlan, J R, *Crops and Man – The Americas*, (American Society of Agronomy: Crop Science Society of America, Madison, Wis., USA), (1992) p. 21.

11 Gorman G, Ancient remains in peru reveal young, female big-game hunter: scientists are divided on broader implications of the find for ancient gender roles, New York Times, 11 (4) (2020). Available online: https://www.nytimes.com/2020/11/04/science/ancient-female-hunter.html

12 Haas R, Watson J, Buonasera T, Southon J, Chen J C, *et al*., Female hunters of the early Americas, *Sci Adv*, 6 (45) (2020) 1-10.

13 Karthikeyan S, Flowering plants of India in $19^{th}$ and $21^{st}$ Centuries – A comparison, In: *Plant and fungal biodiversity and bioprospecting*, S Krishnan & D J Bhat, Eds., (Goa University, Goa, India), (2009) 19-30.

14 Goyal A K & Arora S, Overview of biodiversity status, trends and threats, In: *India's Fourth National Report to the Convention on Biological Diversity*, (Ministry of Environment and Forest, Government of India, New Delhi), (2009) 15-53.

15 Nayar M P, *Hot spots of endemic plants of India, Nepal and Bhutan*, (Tropical Botanic Garden and Research Institute, Palode, Thiruvananthapuram, Kerala, India), (1996) 81-95.

16 Damania A B, Early domestication in South Asia based on archaeological evidence I: Crop Plants, *Asian Agri-History*, 16 (1) (2012) 3-20.

17 Singh A K, Revisiting the status of cultivated plant species Agrobiodiversity in India: An overview, *Proc Indian Natn Sci Acad*, 83 (1) (2017) 151-174.

18 Murthy R S & Pandey S, Delineation of agro-ecological regions of India, In: *$11^{th}$ Congress*, (International Society of Soil Sciences Edmonton, Canada), June 19-27 (1978).

19 Sehgal J L, Mandal D K, Mandal C & Vadivelu S, *Agro-ecological regions of India*, (Technical Bulletin No. 24, Second edition, NBSS and LUP, Nagpur, India), (1990) p. 130-140.

20 Singh A K, Rana R S, Mal B, Singh B & Agrawal R C, *Cultivated plants and their wild relatives in India– An Inventory*, (Protection of Plant Varieties and Farmers' Rights Authority, NASC Complex, DPS Marg New Delhi, India), (2013) 251-262.

21 Mathur P, Trivedi R & Joshi P, *Abrus precatorius* L.: A Review from ethno to nano applications, *Asian Agri-History*, 23 (4) (2019) 245-259.

22 Singh A K & Nigam S N, Ancient alien crop introductions integral to Indian agriculture: An Overview, *Proc Indian Natn Sci Acad*, 83 (3) (2017) 549-568.
23 Paul M, Lata C & Barman P, Irrigation Practices in the Pandya Kingdom, In: *SVASTIK Stories: Indian Traditional Knowledge Through the Lens of Science*, C Lata & P Barman, Eds., (CSIR-NIScPR, New Delhi), (2023) 92-95.
24 Gulati A N, A note on the early history of silk in India, In: *Technical Reports on Archaeological Remains*, J C Brock, K Vishnu-Mittre & A Gulati, Eds., (Deccan College, Poona, Maharashtra, India), (1961) 53-91.
25 Blanton R E, *Ancient Mesoamerica: A comparison of change in three regions*, 2nd Ed., (Cambridge University Press), 1993.
26 Earle R, The Columbian exchange, In: *The oxford handbook of food history*, M. Pilcher & M Jeffrey, Eds., (Oxford University Press, Oxford, UK), (2012) 341-357.
27 Tamang B & Tamang J P, Traditional knowledge of biopreservation of perishable vegetable and bamboo shoots in Northeast India as food resources, *Indian J Tradit Know*, 8 (1) (2009) 89-95.
28 Singh R K & Sureja A K, Indigenous knowledge and sustainable agricultural resources management under rainfed agro-ecosystem, *Indian J Tradit Know*, 7 (4) (2008) 642-654.
29 Sorenson J L & Johannessen C L, Scientific Evidence for Pre-Columbian Transoceanic Voyages, *Sino-Platonic Papers*, (Department of East Asian Languages and Civilizations, University of Pennsylvania, Philadelphia, USA), (2004) p. 273.
30 Simmons I G, *Changing the Face of the Earth: Culture, Environment, History*, (Wiley-Blackwell, USA), (1989) 422-423.
31 Allchin B & Allchin F R, Origins of a civilization: the prehistory and early archaeology of South Asia, (Viking Press, New York, USA), (1997) 81-97.
32 Giri U & Hedayetullah M, *Text Book of Agricultural Heritage*, (Scientific Publishers New Delhi, India), (2020) 21-27.