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History of South Indian Agriculture and Agroecosystems

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While hominin occupation of South Asia may date to as early as 2 million years ago (Petraglia and Allchin, 2007), in South India the earliest evidence for human ancestors appears around 1.2 million years ago at the important Early Paleolithic (Acheulian) site of Isampur (Blackwell, et al. 2001; Paddayya, 2007). It is part of a larger cluster of sites within Hunsgi and Baichbal valleys in northern Karnataka (Paddayya, 1991; Paddayya et al. 2002; Paddayya and Petraglia, 1997). Evidence for Early Paleolithic occupation of southern India is widespread and extensive. Although population sizes were small, evidently these mobile groups of gatherer-hunters dealt successfully with a range of environments. At the deeply stratified site of Attirampakkam near Chennai, Pappu and colleagues (Pappu et al. 2003; Pappu, 2007) noted changes in stone tool production strategies that suggested flexible adjustments to changing conditions. In addition to these open-air sites, Early Paleolithic tools have been recovered from the banks of rivers such as Krishna and Godavari in South India (Morrison, 1999).

The transition to the Middle Paleolithic appears to have been gradual, suggesting no replacement of population (Petraglia and Allchin, 2007); still, technological changes in stone tools were significant and strategies of resource use may have changed quite dramatically as well. Faunal remains are present in significant quantities at a few sites, especially in Andhra Pradesh. During the Middle Paleolithic and following the Toba volcanic "super eruption" 74,000 years ago, the first fully modern humans migrated to the Indian subcontinent, apparently replacing earlier populations (Jones, 2007). Like their predecessors, these Middle Paleolithic inhabitants of South Asia lived highly mobile lives, depending on gathering of wild plants and hunting of wild animals for subsistence. Regional variation was significant in this period, laying the groundwork for the increasing diversification of subsistence strategies into the Upper Paleolithic and throughout the Mesolithic period. While the term Mesolithic is problematic, having been used in multiple incommensurate senses (see Morrison, 2007), here we take it to refer to a time period during the early Holocene, in which diverse *non-agricultural* subsistence strategies were practiced, including mobile gathering and hunting and semi-sedentary fishing and gathering. Mesolithic sites occur across South India, including Chinglepet, Dharampuri, Vellore and Kuttampalli on the Tambraparani river in Tamil Nadu. Notably absent are sites in high-elevation locations in the Western Ghats, suggesting limited use of upland forests, locations that would later become home to many of South India's hunting and gathering groups as lowland agriculture expanded (Morrison, 2002; 2007). The Mesolithic-era in southern India saw significant increases in population, no doubt a factor in both the development and adoption of agricultural strategies.

The development of agricultural strategies in South Asia was a mosaic process, with several centers of domestication emerging at different times in response to local factors. In every case, agriculture continued to co-exist with foraging though many foragers also engaged in pastoralism and trade with nearby agriculturalists (Morrison, 2006). Although the earliest evidence for agricultural production in South Asia dates to the seventh millennium B.C. in the far northwest, in South India permanent cultivation did not develop until around 3,000 B.C. As discussed below, the Southern Neolithic differs in important ways from north Indian Neolithic traditions. There are over 200 Neolithic sites in Karnataka, Andhra Pradesh and Tamil Nadu that have been excavated and studied. Southern Neolithic peoples developed a complex agro-pastoral economy involving both large, permanent settlements as well as extensive regional mobility. They domesticated several kinds of plants and perhaps also animals themselves, as well as adopting cultigens from elsewhere. This southern agricultural tradition was not significantly modified until sometime in the Iron Age (1000 to 500 B.C.) when new crops and strategies were added to productive repertoires.

The focus of this chapter is on the historical aspects of agriculture; mainly its independent invention/introduction in South India, the origin of crops in the South Indian peninsula, on agricultural tools, the development of soil fertility and agronomic procedures, development of agroecosystems, nutrient dynamics and productivity through the ages. While a review of this sort is always selective, we begin with the Neolithic period and end with the present. Special attention is given to the history of agricultural implements, soil fertility, irrigation and finally the development of agroecosystems in South India. However, discussions on many other topics in agricultural history, such as evolution of plant protection methods, post harvest technology, economics and trade are out of the purview of this chapter, considering the theme of the book.

1. History of South Indian Agriculture: Beginnings

It would be extremely useful to have better information regarding the primordial environment, flora and fauna that occurred during the early stages of the invention and introduction of agricultural cropping in South India. Some of the prominent questions that occur are: what were the climatic conditions? What were the extent of forest growth and the distribution of tree species? What was the vegetational composition of wild prairies that eventually gave way for cultivation of agricultural crops? Knowledge about dominant grasses, legumes and other plant species that flourished in these prairies could be useful. Most importantly, the availability of progenitors or wild species of crops seems important. What role did food preferences of prehistoric Southern Indians play in shaping cropping patterns? What was the extent of demand for food derived from crops as opposed to prevailing animal sources? What patterns of seasonality and mobility were established and how did these relate to overall subsistence regimes? Perhaps there are several other questions, equally or more relevant still to be answered. On the basis of available evidence and literature, Asouti (2006) opines that paleoclimatic disturbances induced conversion of dry deciduous forests into wet forests. However, the historical relationship between the peninsula's widespread tropical dry deciduous forests and its less extensive but no less important dry evergreen forests is not widely agreed-upon, with arguments made both that contemporary dry evergreen forests represent highly degraded coastal forests (Ranjit Daniels et al. 2007), and that evergreen forests are a unique form rather than derived anthropogenic formation (Meher-Homji, 2007). Clearly, paleoenvironmental research needs greater attention. In addition to the history of forest change, both human population dynamics and the simultaneous availability of wild progenitors of crop species played an important role in invention of agricultural practices in South India. Woodland openings created via human activity or naturally on forest edges might have contributed to movement of wild species of pulses available inside forests of the Deccan and Western Ghats to the plains. Subsequently, these pulses were domesticated and cultured regularly. Regarding cereals (e.g. small millets), it is postulated that riverine zones, open savannas and hill slopes that supported wild grasses and their progenitors might have provided suitable contexts for their regular cultivation. Indeed, it is worth noting that the earliest evidence of agriculture in the south comes not from the more humid coastal or upland regions but from the dry interior itself.

With regard to timing of initiation of cropping activity in South India, Asouti (2006) postulates that climatic change, especially an increase in humidity during the mid Holocene (5th or 4th millennium B.C.), favored expansion of forests and wet deciduous vegetation around Western Ghats. As the wet phase declined, these forests retreated gradually during mid 4th millennium. Wild species and other food resources available for hunters and gathers in the fringes of forests became relatively scarce. Reduction in naturally available plant food sources and changes in animal habitats, perhaps in association with demographic and/or social changes among foraging groups, could have induced local hunter-gatherer to try cultivation of plant species. The availability of wild species of food crops around Western Ghats, their hill slopes, and plains might have served as a boon to the early inventors of agriculture in South India. The earliest crop species domesticated in the South Indian savannas are small millets, black gram and horse gram. Major tree species that occurred in the scrub lands around sites during early phases of Neolithic period when Southern Indian agriculture got initiated are as follows: *Acacia, Albizia, Anogeissus, Bauhinia, Dalbergia, Grewia, Mangifera, Terminalia, Tectona,* and *Ziziphus* (Asouti, 2006).

1. 1. Agriculture in Southern India during the Neolithic Period

Surprisingly little research explicitly oriented toward studying the origins of agricultural activity in South India have been conducted. According to Fuller et al. (2004), there are at least two lines of evidence to argue that South India played host to an independent origin of agriculture during the Neolithic. Firstly, South India is the region of domestication for several important crops. Indeed, archaeobotanical evidence indicates the occurrence of progenitors of several small millets, tropical pulses and fruits. Remains of these edible plants were traced in permanent Neolithic sites of South India. Many of these crop species might have been domesticated in South India, parallel with but separate from domestication events elsewhere. Chronologically, it may not tally with priority of agriculture in the far northwest. In fact, evidences at Mehrgarh suggest agricultural activity occurred as early as the seventh millennium B.C. (Constantini, 1983). Similarly, evidences for cropping in the so-called Vindhyan Neolithic date back to fifth millennium B.C. Several domesticates of South Indian origin made their way northward to become part of regional crop repertoires. Although South Indian farmers prove to be highly flexible, adopting crops from western Asia, Africa, China, and elsewhere, there is little doubt of the existence of *in situ* domestication in the south.

The period known as the Southern Neolithic differed significantly in many ways from the preceding Mesolithic period. Although sedentary coastal settlements almost certainly existed in South India prior to the development of agriculture, large permanent settlements were only established on a large scale once residents began to combine crop production with intensive animal husbandry. Even after the advent of agriculture in the south, however, Neolithic peoples continued to practice a significant degree of mobility away from permanent habitations, making the archaeological record a complex constellation of small camp sites, seasonal settlements, and large villages. These permanent village settlements and agricultural sites perhaps existed as early as 2800 B.C., with archaeological evidence unequivocally indicating the cultivation of crops in South India by about 2300 B.C. (Gadgil et al., 1997). It is contemporary to Bronze Age urban and agricultural sites in the Indus valley.

Across all of South Asia, agriculturalists co-existed with hunter-gatherers, in some cases right up to the present (Morrison, 2007). This diversity of practices was nowhere as dramatic as in western India, where foragers and Harappan city-dwellers met and exchanged a variety of goods, including domesticated animals and, probably, plants (Kennedy, 2000; Possehl, 2002). This co-existence was also the case on the peninsula, where the Southern Indian Neolithic or 'Ashmound' tradition flourished between ca. 3000

Note: Neolithic Period: Phase-1 spans 2600 B.C to 2200.B.C.;
Phase-2 from 2300 B.C to 1600 B.C. and Phase -3 from 1700 B.C to 800 B.C.

and 1200 -1000 B.C. The complex agro-pastoral economy (Allchin and Allchin, 1982; Korisettar et al. 2001a) of the Southern Neolithic involved intensive cropping as well as animal husbandry, hunting, and the gathering of wild plants. While ashmounds are found across only part of South India, these distinctive features have excited much attention and study. Large mounds or heaps of highly-fired cattle dung, these vitrified features served as key in a regional geography that included both short-term camps and large, permanent settlements (Morrison, 2008). Explanations for the heaping and burning of such large dung piles have varied, with some scholars (Allchin, 1963; Johansen, 2003) stressing social and ritual factors and others (e.g. Paddayya, 1974; 1992) more utilitarian economic accounts. Although there is clear evidence for cattle - penning, there is little doubt that ash mounds were products of deliberate burning and not the remnants of accidental fires. It is worth noting, however, that dung was not apparently used either for fuel or manure at this time (Fuller, 2005a).

There are many Neolithic sites in Northern and Eastern Karnataka that indicate, permanent agriculture. Mostly these settlements were situated on or near the granite hills and peaks that make up much of the terrain in Karnataka and Andhra Pradesh. With some important exceptions such as the large Neolithic settlement at Brahmagiri (Wheeler, 1947), many of the more permanent settlements were located on terraces and in castellated regions. Full-fledged Neolithic sites belonging to phase-2 and 3 are found in Nagarjunakonda in Andhra Pradesh (Singh, 1990). Permanent settlements without ashmounds were common on alluvial plains (Fuller et al. 2004). Sedentary agricultural settlements occurred in the Tamil Nadu region of South India around 3rd to late 1st millennium B.C. Archaeological sites in Tamil Nadu, especially those in the districts of Coimbatore (Kodumanal, Perur) and Madurai (Mangudi), proved that sedentary agricultural societies existed there, and utilized a variety of stone implements. Neolithic sites in locations such as Mangudi in Madurai, and Perur in Coimbatore were built in locations earlier inhabited by hunter-gatherers, a pattern common across the region. Similarly, Neolithic sites around Coimbatore and Erode indicate cotton cultivation and use of stone implements (Fuller, 2005b). There are several other Neolithic agricultural settlements excavated and studied in Tamil Nadu, namely at Gollapalli, Bargur and Tograpalli in Krishnagiri district and at Paiyampalli in North Arcot. These sites indicate that both permanent agriculture and pastoralism were practiced (Ramachandhran, 1980).

Some reports suggest that Neolithic agriculture did not make its mark in Kerala or in other parts of the southwest coast. While some of this pattern may relate to a lack of research, it may indeed be the case that the humid tropical forests of the region were more difficult to colonize (Morrison, 2002). Excavations of prehistoric sites have not yielded sizeable tools, pottery or crops to indicate Neolithic agriculture. Most of the locations possessing agricultural artifacts belong to the Iron Age spanning from 800 B.C. to 50 A.D.

Examination of plant remains using the flotation technique and carbon dating suggested that farmers or pastoral groups in these Neolithic sites (villages) located on hill tops regularly cultivated small millets (*Brachiaria spp*), bristly foxtail millet (*Setaria verticillata*), grasses, pulses such as mung bean (*Vigna radiata*) and horse gram (*Macrotyloma uniflorum*) (Table 1.1). According to Fuller (2005a), these crops are native to South Indian cropping zones. Perhaps, the above crops and certain tubers were domesticated during the Neolithic. Most of the evidence gathered indicates that the earliest agriculture in South India dates to the 3rd millennium B.C. This inference was based on crops domesticated *in situ*. Subsequently, from the late 3rd millennium B.C. through the 2nd millennium B.C. additional crops from other regions were adopted into the subsistence regime of South India (Fuller et al. 2004). Forest tree species that existed around the permanent settlements, say at the time of independent domestication of crops in South India (3rd millennium B.C.), were deciduous species such as *Tectona grandis, Anogeissus latifolia, Terminalia tomentaosus* etc. *Acacia* and *Albizzia* scrubs were also found frequently in samples of charred wood from these Neolithic agricultural sites in South India. Around these settlements, vegetation was generally dry or evergreen scrubland with dotting deciduous trees (Fuller et al. 2004). *Piper nigrum*, found in archaeological contexts in South Asia and as far afield as Egypt (Cappers, 2006) was almost certainly a trade product from the more mesic upland forests.

Table 1.1 Domesticated or Introduced Crops and Animals attached with South Indian Neolithic Agricultural settlements, especially in North Karnataka and Andhra Pradesh

CROPS

Large Cereals:
Barley (*Hordeum vulgare*); Wheat (*Triticum aestivum* and *T. dicoccum*); Rice (Oryza *sativa*)
Millets and Forage Grasses:
Brown top millet (*Brachiaria ramosa*); Bristley foxtail millet (*Setaria verticillata*);
Sawa millet (*Echinochloa colona*); Yellow foxtail millet (*Setaria pumila*); Little millet (*Panicum sumatrense*); Kodo millet (*Paspalum scrobiculatum*); Pearl millet (*Pennisetum glaucum*); Finger millet (*Eleusine coracana*)
Pulses/Legumes:
Pigeon pea (*Cajanus cajan*); Mung bean (*Vigna radiata*); Urad (*Vigna mungo, V trilobata*); Hyacinth bean (*Lablab purpureus*)
Miscellaneous crops:
Cotton (*Gossypium arboreum*); Flax (*Linum usitatissimum*), Fig (*Ficus sp*); Jujuba (*Ziziphus sp*); Java Plum (*Syzigium cumini*); Cucumber (*Cucumis prophetarum*); Luffa (*Luffa cylindrical*); Okra or Bhendi (*Abelmoschus esculentus*)
Trees:
Toddy Palm (*Borassus flabelliformis*); Tamarind (*Tamarindus inidcus*); Palas (*Butea frondosa, Erythrina indica*), other trees mentioned in scripts related to Southern Neolithic sites are Teak, Mango, Pipals, Bamboos, Jujuba and Coconut palm.

Note: Crops currently in common use but not traceable in southern Neolithic sites are as follows:
Sugar cane (*Saccharum officinarum*); Sesame (*Sesamum sp*); Hemp (*Cannabis sp*); Onion/garlic (*Allium sp*); Eggplant (*Solanum melangina*); Peanut (*Arachis hypogaea*). Sunflower (*Helianthus anuus*)

ANIMALS

Cattle: Cow (*Bos indicus*); Buffalo (*Bos bubalis*)	Sheep (*Ovis aries*); Goat (*Ovis aegagrus*)
Dog: *Canis familiaris*	Cat: *Felix domestica*
Horse: *Equus caballus*	Ass: *Equus asinus*
Swine: *Sus scrofa cristatus*	Poultry :*Gallus sp*

Source: Southworth 2006; Fuller et al. 2004; Korisetter et al. 2001 a, b; Thomas, 1974; Manasala, 2000; Misra, 2001;
Note: Southern Neolithic settlements were closely integrated and compact. Perceptions regarding soil fertility, crops, residue recycling, animal fodder and nutrients derived from cattle/sheep penning zones might have been understood by the population.

Southworth (2006) suggests that during phase-2 of the Southern Neolithic, humans in permanent dwellings practiced agriculture that was well accompanied by pastoralism and hunting. Nutrient flows within settlements must have been stringent owing to physical closeness of crop fields and penning zones of domesticated cattle, sheep, chicken, swine etc. Korisettar et al. (2001b) report that Neolithic dwellings examined by them possessed evidence for domesticated animals and other fauna. Rock paintings and etchings showed that Neolithic agriculturalists in these areas in North Karnataka coexisted/or utilized fauna around them effectively. Faunal depictions mostly related to horses, bulls, deer, gazelles, peacocks, squirrels, canines, felids, bears, primates and serpents. They also reported domesticated sheep, goats and cattle. About 21% of the sites possessed evidence for regular use of chicken.

1. 2. Origin and Evolution of Agricultural Crops in South India

South India is considered the origin and major center of genetic diversity for a wide range of crops that include cereals, legumes, oil seeds, fruit trees and wood species. Let us consider crop species that were domesticated and/or introduced into South India during the Neolithic period. In view of the theme of this book, discussions are confined to few important cereals and legumes commonly traced in excavations and other investigations. Although it is tempting to focus on the domestication of crop species such as rice, pearl millet, foxtail millet, finger millet, pigeon pea, cowpea, horse gram, linseed, and cotton that are so important to the complex agroecosystems of today, in fact, the true foundations of agroecosystems in South India were established during Neolithic period, beginning in the 3rd millennium B.C and included *in situ* domestication. While certain crops of western Asian origin such as wheat or barley do appear in South Indian crop regimes as early as the Neolithic, these had only limited importance in the region. Introduced crops such as rice, sorghum, finger millet, cajanus and others flourished during later periods and became important components of later agroecosystems. Firstly, let us consider evidence for their cultivation and use by Neolithic human cultures that existed in South India.

Rice, Millets and Grasses

Rice is an important crop of South India. Progenitors of rice such as *O. rufipogon* and *O. nivara* are generally well distributed in the eastern Gangetic plains. The oldest evidence for rice cultivation in India has been obtained from sites such as Koldihwa in Uttar Pradesh. Their dates were estimated at 6570 B.C. to 4530 B.C using associated radiocarbon dates; however, these early dates have not been widely accepted and most scholars conclude that domesticated rice first appeared during the 3rd millennium B.C. in the Gangetic plains, with little credible evidence, at presence, for a local domestication of rice. By ca. 2500-2000 B.C., rice is found in sites in western India and the Indus region (Fuller, 1999). Its presence in South India was negligible even during 2nd millennium B.C., notwithstanding a few charred rice grains from Neolithic sites in Karnataka reported by Fuller et al. (2004).

Rice cultivation became widespread by the 1st millennium B.C, with rice eventually taking the role as one of South Asia's most important cultigens. It is generally agreed that domesticated rice was introduced from Northeast India to South India sometime during the 2nd millennium B.C. Randhawa (1980) states that rice cultivation spread from Orissa into wetter zones of Andhra Pradesh and Tamil Nadu during the Iron Age, around 300 B.C, though there is little direct evidence for this statement. Although Fuller et al. (2004) suggest that rice could have been domesticated independently in Southern India around the 1st millennium; genetic evidence would not support this. Domestication of several cereals and pulses does, in fact, suggest independent beginnings of agricultural activity in South India. However this process probably did not include rice. The independent origin of agriculture in South India is chronologically late compared to other parts of world like West Asia, Northwest India, and East Asia, but the importance of local processes of domestication in this region should not be underestimated. According to Kipple and Ornelas (2006), initially rice was used as supplement to other food plants, game and fish. However, later its cultivation spread and replaced other cereals, a pattern consistent with our current understanding of South Indian agricultural history.

Archaeobotanical studies indicate that millets were in use in South India as early as 3000 B.C. to 2500 B.C. In contrast to the relatively late appearance of rice, millets were dominant here and in Gujarat (western India) much earlier. Most of the Neolithic locations in North Karnataka and Andhra Pradesh that were examined by Fuller et al. (2004) indicated presence of caryopses and other plant parts of millet species such as *Setaria, Echinochloa* and *Brachiaria.* Specimens of *Setaria sp,* non-dehiscent domesticated *Echinochloa, Paspalum* and *Eleusine coracana* were also recorded (Fuller 1999; 2005a). *Setaria sp* was widely cultivated in South India. However, in modern times *Setaria verticillata* is gathered from wildly growing stands around forests in South India. It may sometimes be cultivated for grains.

There are reports that domesticated finger millet (*Eleusine coracana*) occurred among Neolithic sites (2nd millennium B.C.) of South India (Fuller 1999; 2005a; Devaraj. 1995; Vishnu-Mittre, 1971). Fuller et al. (2004) report *E. coracana* specimens found in permanent settlements in North Karnataka, perhaps belonging to Neolithic Phase-3. Cereals such as *E. coracana* and *Sorghum bicolor* were traced at several Neolithic sites, namely, Gollapalli, Payimpalli, Tograpalli and Bargur in Tamil Nadu (Ramachandhran, 1980).

Archeological remains of sorghum have been reported from Neolithic sites of South India. However, sorghum was originally domesticated in Northeast Africa around 3000 B.C. or earlier. It spread to the Southern Indian peninsula between ca. 1500 and 1000 B.C. Fuller (2006) states that several crops of African origin, including sorghum, had diffused into South India during the 2nd millennium B.C. Investigations of Neolithic sites in North Karnataka clearly indicate the use of *Sorghum bicolor.* Sorghum derived from both Northeast Africa (Ethiopia) and Mozambique ports are traceable in southern Neolithic sites.

Fuller et al. (2004) report *Pennesitum glaucum* in sievings of plant material from several locations of North Karnataka, especially Hallur, a site occupied from the end of the Southern Neolithic and into the Iron Age. The earliest dates for *P. glaucum* in South Asia come from Daimabad, 2000-1700 B.C. (Kajale, 1977). Although Fuller et al.'s material is not well-dated, they suggest that the presence of *P. glaucum* caryopses indicates the occurrence and cultivation of pearl millet around the first half of 2nd millennium B.C. It is suspected that *P glaucum* is an introduced species derived from northwest India. Domestication of *P. glaucum* occurred in the upper reaches of the Niger River in West

Africa, sometime around 4000 B.C. to 3500 B.C. Both West Africa and Northwest India are considered as centers of genetic diversity.

Grasses such as *Paspalum scrobiculatum* and *P. miliaceum* have been reported from the Neolithic sites at Kurugodu and Hallur. Based on study of caryopses and plant debris, it was concluded that most of these archaeological samples of *Paspalum* (caryopses) belong to 2nd millennium B.C. (Fuller et al. 2004; Saraswat et al. 1994). *Paspalum* was, however, more frequent in settlements of 1st millennium B.C. Grasses such as *Echinochloa colona* was traced in North Karnataka and Andhra Pradesh. Based on seed traits such as scutellum, hilum and shape it was concluded that *E. colona* was common to flora of Neolithic sites (Fuller et al. 2004).

Hordeum vulgare (barley), *Triticum dicoccum* and *T. aestivum* (wheat) as well as flax were traced in collections from southern Indian Neolithic sites (Fuller et al. 2004). These represent adoption of crops imported from Southwest Asia via the North Indian plains. As noted, domesticated wheat and barley have been found in Pakistan as early as the 7th millennium and only a little later in Baluchistan and northwest India. A study of ceramics, utensils, and food habits along with crop species can be very useful while judging Neolithic agricultural patterns. Evidence from ceramics and other culinary items suggests that winter cereals such as wheat and barley were not produced in Southern Neolithic during early phase-1. Ceramic utensils consistent with bread making and utilization such as flat plates and bread platters commonly found in Harappan locations of the third millennium B.C. were not traced in South India during the early Neolithic. However, evidence for wheat is more common during the Neolithic in Maharashtra and the North Deccan. Fuller (2006) has argued that the utilization of bread as a culinary item gains in currency only during the later phases of the Neolithic period in South India. Further, he suggests that many vessel forms used for serving, such as ceramic and iron plates from the Gangetic region, were adopted into South India only much later, during the Iron Age (ca. 500 B.C.). Although they never became a dominant part of the cultivated flora, winter cereals such as wheat or barley never disappeared from Southern India where they were sometimes locally important. Certainly, however, by the 2nd or 1st millennium B.C., rice, sorghum and small millets that thrive better in tropics/subtropics of South India replaced these winter cereals almost entirely.

Pulses and other crops

Native Southern Indians have grown pulses and legume crops at least for the past 4 to 5 millennia. These legumes have supplemented their diets with proteins, sometimes entirely or partly along with animal proteins. There are several pulse/legume crops whose geographical origin is in South India. Some of them were domesticated *in situ* in South India, but not all. Most of these legumes were domesticated around 3 or 2nd millennium B.C. in the peninsular region. A few of them were introduced into the region later. Often, conclusions regarding origin, center of diversity and points of domestication have been decided based on species richness, extent and intensity of cultivation of crop as well as archaeological evidence from charred seeds, plant parts, or drawings. In addition, historical literature provides useful support (Nene, 2006). The following is a list of legumes cultivated in South India, their geographic origin and probable area of domestication:

Crop: Pigeonpea (*Cajanus cajan*)
Geographic Origin and domestication: South and Central India, Western Ghats
Vernacular names: *Tur* or *Tuvar* in Hindi; *Togari* in Kannada; *Kandhi* in Telugu; *Parappu* inTamil, *Vanpayir* in Malayalam
Crop: Black gram (*Vigna mungo*)
Geographic Origin and domestication: South India
Vernacular Names: *Masha* or *Mugdaparni* in Sanskrit; *Urd* in Hindi; *Uddhina bele* in Kannada; *Udhu* in Telugu; *Ulundu* in Tamil, *Uzhunnu, Uzhunnu parippu* in Malayalam
Crop: Green gram (*Vigna radiata*)
Geographic origin and Domestication: Western Ghats in South India
Vernacular names: *Mung* in Hindi; *Hesara bele* in Kannada; *Pesara popu* in Telugu; *Pasipayir* in Tamil; *Pachepayir* in Malayalam)
Crop: Horse gram (*Macrotyloma uniflorum or Dolichos biflorus*)
Geographic origin and Domestication: South India, Western Ghats and Plains in Karnataka, Andhra Pradesh and Tamil Nadu
Vernacular names: *Kulatha* in Sanskrit; *Kulthi* in Hindi; *Huruli* in Kannada; *Kollu* in Tamil, Kulattha or *Valuvu* in Telugu), kesari bele in Malayalam
Crop: Chickpeas (*Cicer arietinum*)
Geographic Origin and domestication: Turkey-Syria
Vernacular names: *Khalva* in Sanskrit; *Chana* in Hindi, *Kadale* in Kannada, senag pappu in Telugu; Kadala in tamil *Kadala* in Malayalam
Crop: Cowpea (*Vigna ungiculata*)
Geographic origin and Domestiction: West Africa
Vernacular names: *Alasaka* in Sanskrit; *Lobia* in Hindi, *Alasande* or *Chowli* in Kannada, *Alasandulu* in Telugu, *Karamani* in Tamil, Malayalam
Crop: Peas (*Pisum sativum*)
Geographic origin and domestication: Southern Europe
Vernacular names: *Matachi* in Sanskrit, *Matar* in Hindi, *Vatana* in Telugu, *Vatani* in Kannada, *Patani* in Tamil

Crop: Lathyrus (*Lathyrus sativus*)
Geographic origin and Domestication: Southern Europe
Vernacular names: *Triputa* or *Khanidka* in Sanskrit, *Khesari* in Hindi, *Khesari parippu* in Tamil, *Lanka pappu* in Telugu, *Kesari bele* in Kannada.

Source: Nene, 2006; Fuller, 2005 b; Korisettar et al. 2001 a, b
Note: Some of the legumes stated above were domesticated elsewhere; their geographic origin too is not in South India. However, they were introduced early during the Neolithic (3200 B.C. to 1000 B.C.) or Iron Age/Early Historic (1000 B.C. to 500 A.D) into the Peninsular region of India.

Pigeonpea (*Cajanus cajan*) is native to the Southern Indian peninsular region. *Cajanus cajan* was actually derived from its wild progenitor *C. cajanifolia*. At present, *C. cajanifolia* is rare because of loss of its habitat to domesticated crops. Several other *Cajanus sp* (formerly *Atylosia*) is confined to tropical vegetation in Western and Eastern Ghats and Sri Lanka. *Cajanus* seeds were regularly traced through sieving and from flotation samples from Neolithic sites in North Karnataka. At Sanganakallu and Hallur, Cajanus samples belonged to the Neolithic phase-3 period (Fuller et al. 2004). It is believed that *C. cajan* crops were robust and yielded well considering the nature of preserved samples examined by archaeologists. Evidence for domestication and regular cultivation of pigeonpea are also available in historical literary works. For example, Pigeonpea is called *adhaki* in Sanskrit works such as *Susruta samhita* (400 B.C.) and *Charaka samhita* (700 A.D.) (Krishnamurthy,1991; Vidhyalankar,1994). In the Sanskrit lexicon *Amarakosha* written by Amarasimha, pigeonpea is called by different names such as *Adhaki, Kakshi* and *Thuvarika* (Jha, 1999). *Tuvarika, turri* or *tur* are variants to denote pigeonpea. Perhaps pigeonpea was introduced into deeper South India much later, around 100 B.C to 300 A.D. (Achaya, 1998; Nene, 2006).

The geographical origin and region of maximum diversity for commonly used legumes, namely *Vigna radiata* and *V. mungo* spreads across the area from Southwest Maharashtra to the Western Ghats in Karnataka and Kerala (Ignacimuthu and Babu, 1985). Based on archaeological investigations in North Karnataka, Fuller et al. (2004) suggest that progenitors of *Vigna radiata* are easily traceable in samples belonging to Neolithic or Chalcolithic period. Perhaps *V. radiata* was domesticated by the end of 2nd millennium B.C. in the Deccan (Vishnu-Mittre, 1961; Kajale, 1975; Fuller et al. 2004). Archeological examination of Neolithic sites at Gollapalli, Tograpalli and Bargur in Tamil Nadu, have also proved cultivation of pulses such as green gram and black gram (Ramachandhran, 1980).

Horse gram (*Macrotyloma uniflorum* or *Dolichos biflorus*), known as *kulthi*, is a small sized crop native to Southern Indian dry lands. It was domesticated during the Neolithic period on the Indian peninsula. Fuller et al. (2004) report that archaeological samples from North Karnataka and Andhra Pradesh, dating around the 2nd millennium B.C., contained flat, trapezoidal seeds and cotyledons of horse gram. Wild species of *Macrotyloma uniflorum* are yet unknown. The region of maximum diversity that occurs in the shrub vegetation zones of the southern states needs to be searched and progenitors, if any, identified. Archaeological remains of horse gram have also been reported from several Neolithic sites in Tamil Nadu (Ramachandhran, 1980).

Seeds of cotton with lint attached to them were noticed in Neolithic sites of South India. These specimens from Hallur and other locations belonged to *G. arboreum*. This species of cotton is considered native to North Karnataka, whereas, *G. herbaceum* is an introduced species of cotton. Linseed (*Linum usitatissimum*) was also collected from Neolithic settlements in North Karnataka. The cultivated species *L. usitatissimum* and indigenous *L. mysurense* were both recorded. Several types of cucurbits were also noticed in Neolithic settlements in South India. *Cucumis prophetarum* is said to be native to South India. *Luffa cylindrica* was another cucurbit species domesticated by Neolithic people in South India. Further, Fuller et al. (2004) suggest that climatological shifts around 3rd and 2nd millennium B.C. might have induced the introduction of new crop species and cultivation of non-native species such as *Triticum, Hordeum* certain *Vigna* species and others, in South India.

1.3. Agricultural Crop Diffusions into and out of South India

In the context of this chapter, 'diffusion' or 'counter diffusion' as suggested by Fuller (2006), refers to crop introductions and expatriation from a region to other. At present in the 21st century, the Southern Indian agricultural belt supports a large diversity of crop species and their genotypes. Many of these crop species originated in locations such as Africa, West Asia, Southern Europe, South America and China. Obviously, these were introduced or diffused into South India at some point of time in agricultural history. According to Fuller (2006), rice, wheat, barley, setaria, sorghum, millets, pulses, oil seeds, gourds and cucumber form the 'basic food crop package of South India'. A few of the native crops from 'South Indian Neolithic package' moved to other cropping zones in the subcontinent and perhaps elsewhere.

During the course of agricultural evolution in the southern Neolithic zones, crops originating elsewhere were added into the subsistence system (Fuller et al. 2004, Fuller, 2006; Korisetter et al. 2001b). Such introductions also included domesticated animals and their breeds. Fuller (2006) argues that in various horizons of excavations belonging to 2nd millennium B.C. (2500 -2000 B.C), wheat (*T. aestivum* and *T. durum*) as well as barley (*Hordeum vulgare*) occurred consistently together and in small quantities in southern Neolithic sites like Sanganakallu. These cereals diffused into the Southern Neolithic region from West Asia. They were initially (2500 B.C.) found in small quantities, later becoming more important locally. Still, as noted, wheat and barley remained specialty crops in South India and were never the dominant cultigens. Similarly, there is clear evidence for the diffusion of crops such as sorghum, pearl millet and cowpea from Africa during the Southern Neolithic (Fuller, 2006). Several other crops such as *Cajanus* and cucurbits were introductions from North Deccan into South India. Around 1800 B.C., several other crops were repeatedly introduced into the Southern Indian agricultural terrain. For example, wheat (*Triticum sp.*), pearl millet (*Pennesitum glaucum*) barley (*Hordeum vulgare*) and hyacinth were introduced from northwestern region of Indian sub-continent (Fuller, 2005a).

As stated earlier, small millets and pulses such as black gram (*V. mungo)* and horse gram (*Macrotyloma uniform*) form the basic Southern Neolithic package of pulses (Fuller, 2006). On the other hand, North Deccan and the Malwa region where cultivation of wheat and barley were much more intensive, is markedly different in terms of archaebotany. Fuller (2006) suggests that crop species from the Southern Neolithic, especially *V.mungo, M. uniflorum* and small millets, including those derived from Africa (for e.g. sorghum) diffused to the northern Deccan, Northwest India and even East Asia. Hence, he suggests counter currents of diffusion of crop species in both directions. Winter crops of West Asia such as wheat and barley moved southward from northwest, while southern Neolithic crops moved northwards. However, during later periods of history, intense crop selection and preferences meant that, tropical crops like rice, sorghum, pigeon pea and other pulses replaced winter cereals such as wheat and barley. These tropical crops have developed into large expanses and agroecosystems. Agroclimate, water resources and soil nutrient status might have played crucial role in movement and establishment of new crops either way, into or outside of Southern Indian Neolithic sites. Of course, food habits and preferences, too influence cropping pattern in a location, be it in Neolithic or modern times.

The geographic origin of chickpea (*Cicer arietinum*) is in Turkey and Syria. In general, West Asia is said to hold maximum genetic diversity of this crop. Till date, 30 to 40 wild species have been identified. The cultivated species entered Southern India during early Neolithic period. There are several indications in ancient Sanskrit literature that cultivation and use of chickpeas was established during the Neolithic and later stages of the history of South India. Chickpeas were used during Rig Vedic period. This legume was known as *Khalva. Brihadaranyaka* (2500 B.C.) mentions use of legume grain called *Khalva* (Nene, 2006). *Yejurveda, Upanishads, Aranyakas* and other Sanskrit works too document the use of *khalva. Charka Samhita* states that chickpea soup provided health to the populace. Similarly, *Susratha samhita* (400 B.C.) states that cooked chickpea and their leaves were nutritious items (Krishna Murthy, 1991). Much later, Kautilya's *Arthashastra* mentions that roasted *khalva* or *kalaya* was consumed in India. The occurrence and use of chickpeas, also called *Chanaka* was recorded in ancient relics. Chickpea was regularly cultivated in Andhra Pradesh, Karnataka (*Kadale*) and Kerala (*kadala*). Kashyapa's *Krishisukti* (800 A.D.) mentions cultivation of at least two different genotypes of chickpea, one with a large seed and other small seeded (Nene, 2006).

Cowpeas are native to West Africa. The region of maximum of genetic diversity as well as of earliest domestication is the West African tropics. Cowpeas were introduced to India some 4000 years ago. The earliest archaeological appearance of Cowpeas to date is at Daimabad, in western India, during the second millennium B.C., where a range of varieties seems to have been present. Like West Africa, India is also a location of high genetic diversity for cowpea. Its cultivation and use has been documented in *Charaka Samhita* (700 B.C.) as *rajmash*. In other Sanskrit treatises it is known as *Chavala* or *Chapala* (Jain, 1984; Nene, 2006). South Indians have regularly cultivated and consumed cowpea since the middle Iron Age (500 B.C.).

Peas (*Pisum sativum*) are native to southern Europe. They were introduced into the Indian subcontinent during prehistoric times, though the route and exact timing of the entry of peas into South India is unknown so far. Archaeological study aimed at understanding earliest cultivation and use of peas in South India is needed. Its cultivation was in vogue in India during late Neolithic period phase-3. Evidence for cultivation of pea is available in *Amarakosha*, a Sanskrit lexican written by Amarasimha dating 200 B.C. (see Nene, 2006). The Sanskrit word for peas is *Matachi*. Varahamihira (350 - 400 A.D.) mentions use of peas (*Vatala*). In southern Indian languages, it is called *Vatani* in Kannada, *Vatana* in Telugu or *Patani* in Tamil.

The grass pea (*Lathyrus sativus*) is once again a native European crop. Available archaeological evidence indicates that it was grown in India around 2000 B.C. (Mehra, 2000). The probable route and period of introduction to Indian subcontinent is not clear. It is mentioned as *Triputa* or *Khandika* in ancient Sanskrit literature. It is called *Khesari dhal* in Hindi, *Khesari parippu* in Tamil, *Lanka pappu* in Telugu and *Kesari bele* in Kannada

2. Agriculture in South India during the Iron Age and Early Historic Periods (1000 B.C. to 1000 A.D)

The South Indian Iron Age (1000-500 B.C.) was a time of significant agricultural change across the peninsula. This period saw the establishment of the first very large, permanent habitations, settlements that might even be considered small cities. Along with this change in settlement pattern were associated changes in cropping and diet as well as a major expansion in long-distance trade (Bauer and Morrison in press; Morrison 2008). These trends continued into the Early Historic period (500 B.C. - 500 A.D. with the latter part extending to about A.D. 1000), when we first have direct evidence from texts as well as archaeological remains. Megaliths, once associated exclusively with the South Indian Iron Age are now known to have been built well into the Early Historic and perhaps even beyond (Morrison, 2008). Unfortunately, many archaeological sites from these periods are not well dated and the intensity of study into agricultural practices has not yet reached the level devoted to the preceding Neolithic. One of the most important trends across these centuries is certainly the extension of rice cultivation on a large scale, a process that may have begun in the Iron Age and which was certainly well established by the Early Historic.

Although much work remains to be done, it is clear that Iron Age farmers intensified production relative to their Neolithic forbears, with at least some practicing a relatively intensive form of agriculture involving seasonal inundation from perennial rivers (Morrison, 2008). While iron tools did not fully replace chipped and ground stone implements, they were common enough to be used for many everyday tasks, including crop processing. Archaeological evidence from animal bones indicates that cattle were used for traction and for secondary products such as milk (Bauer, 2007). While established cultivars continued to be grown, several crops were adopted into South India between 1000 B.C. and 500 A.D. via various routes such as migrations, trade and conquest. In this period we have evidence for the first reservoirs (tanks), features that allowed the highly seasonal rainfall to be somewhat more evenly distributed. Even though many Iron Age reservoirs appear to have served ritual rather than economic ends (Bauer and Morrison in press), there is little doubt that this new technology would prove critical for the success of farming in the drier parts of the region. Agricultural land was partitioned to crops such as cereals (rice, millets); legumes (*Cajanus cajan, Phaseolus sp, Macrotyloma uniflorum*); oil crops such as safflower, sesamum, mustard, linseed; vegetables such as pumpkin, gourds, pepper; as well as several others like sugar cane, and horticultural species like mango, jambu, plantain (kadali), palm, grapes.

Archaeological evidence from the Early Historic sites also indicates the use of spices such as long pepper, black pepper, ginger, cumin, coriander etc. Many of these products grew only in the uplands of the Western Ghats and would thus have been traded long distances. Indeed Malabar pepper was world-famous by the first few centuries B.C. The significance of the long-distance trade in pepper to the Roman world, well known through texts, is attested archaeologically by the recovery of more than 7.5 kg. of pepper from the port of Berenike on the Red Sea (Cappers, 2006).

Knowledge about genetic variability of crops allowed ancient farmers to select different cultivars to suit agroclimates and soils. Human preferences and economic considerations too dictated the particular crop and its genotype sown in fields. For example, historical records, literary works and archaeological investigations all indicate that Southern Indians cultivated several different types of rice to suit different culinary and nutritional requirements of the populace. For example, regarding rice varieties with specific nutritional factors, sage Kashyapa's *'Kashyapiya Krishisukti '* mentions that 'golden colored rice' was cultivated by farmers around 700 to 800 A.D. (Somasekhar, 2003). This golden rice called *'Pithavarna vruhi'* or 'yellow rice' is known to be rich in vitamin A. Similarly, 'Hema' is golden rice rich in Vitamin A.

Evidence gathered from Sanskrit literature pertaining to agriculture in these periods indicate that farming practices were well standardized to suit location, soil fertility status, seasons and farmers' abilities. Pathanjali's (200 B.C.) Mahabashya suggests that, firstly fields are to be cleared, then ploughed using ox-drawn plough. Immediately after ploughing, seeds are sown. Fields were classified as *Vraihya, Saleya, Yavya* and *Anavya* based on seed types sown in them. Crops sown varied, but they were matched to suit season, soil type and water resource. For example, rice was sown immediately as the rainy season begins, but water requirements for transplantation and periodic irrigation were usually met through tanks (Nigam, 1975). Transplantation of crops was also in vogue during ancient period. Interestingly, there are clear suggestions, that mixed cropping or inter cropping was practiced by ancient Indian farmers.

Pathanjali's (200 B.C.) Mahabashya identifies following stages of crop production; namely, clearing fields to remove stones and weeds, ploughing, sowing, irrigating, fencing, watching, reaping and threshing (Nigam, 1975).

There are historical records that discuss agroclimate, soils and agronomical aspects of pulse production in Ancient India. Kautilya's(321-296 B.C.) *Arthashastra* states that pigeonpea (*udhaaraka*) is sown early in the monsoon to coincide with the onset of rains (Shamasastry, 1961). Kashyapa's *Krishisukti* mentions different varieties of pigeonpea differentiated by stature and maturity period (Ayachit, 2002). Pigeonpea types were also distinguished based on seed color. For example, *Sivatatvaratnakara* mentions that a black seeded pigeonpea known as *Krishnadhika* was grown in Karnataka (Achaya, 1998).

Ancient Indians used chickpeas or *Khalva* regularly in their diets. Kautilya (321-296 B.C.) mentions use of chickpeas. Regarding its cultivation practices, his *Arthashastra* mentions that grains of *khalva* should be soaked ahead for 3 to 5 days and sun dried before sowing. Kashyapa's *Krishisukti* states that legumes such as *khalva* are grown as a rain fed crop, without much effort to irrigate them. Moistened seeds are broadcast or sown in lines (Ayachit, 2002). Chickpeas were grown during the period after the rainy season. Manuring with cow dung to improve soil quality and fertility were also suggested. Weeding should be initiated within a month of sowing to avoid competition for soil fertility factors. Nene (2006) mentions that *Krishisukti* contains information regarding different genotypes of chickpeas, their adaptation to prevailing agroclimates during ancient periods. Further, he suggests that farmers had developed some ideas regarding environmental interaction and its influence on pod yield.

Horse gram (*Macrotyloma uniflorum*) was cultivated in all seasons. It is a hardy legume that adapts well to harsh agroclimate and still provides proteins for farmer's subsistence. Kashyapa's *Krushisukti* (800) A.D. mentions that horse gram is a drought tolerant plant. It needs weeding to avoid competition for soil factors. Horse gram is grown as intercrop with cereal grain crops or grasses such as *Paspalum* (Nene, 2006).

In addition to field crops, agricultural practices in ancient South India included culture of fruit trees and woody species. Fruit trees included citroen, kola (Jujuba) and parushaka (*Grewia asiatica*).

Shifting cultivation was also practiced in the hilly tracts of South India and forest openings. Farmers practicing 'shifting agriculture' cultivated crops such as rice, millet, cotton, vegetables and bananas. The Sangam literature (2nd century B.C. to 2nd century A.D.) emanating from Tamil region of South India is an important source of information on agriculture during the Iron Age (Abraham, 2003). Its study indicates that both agro-pastoral and partly nomadic agriculture were practiced in Tamil region of South India. It also mentions use of iron implements for raising crops. There are several Iron Age (27 B.C. to 14 A.D.) sites near Thirunalveli, Madurai, Palni hills, Pudukotai, Salem and Dharampuri in Tamil Nadu that indicate the use of iron implements and tools for agricultural activity (Ramachandhran, 1980).

3. Agriculture in Medieval South India (1000 A.D. to 1700 A.D.)

Agricultural production was a critical feature of life for people in the Medeival (Middle period) kingdoms of South India. Large cities of this period were located in both rich alluvial deltaic lowlands as well as semi-arid and rocky uplands. Although all large settlements faced the need for intensive food production, strategies differed significantly depending of local climates, soils, and food preferences. By this period an elite cuisine based on irrigated crops was well developed, making the distinction between the rice-based foods of the well -to -do and the millet-based foods of the poor (Morrison, 2001). In the semi-arid regions of the interior, then, a wide range of irrigation facilities were developed in order to make the production of wet rice and other irrigated crops possible. Trade in spices and aromatics such as black pepper and ginger continued into this period. It is the trade that eventually draws European trading companies into the region. Cotton, too, was grown on a large scale and moved to areas of textile production, but grain cropsappear to have been more locally produced for the most part (Morrison, 2000).

During the Vijayanagara era from 14th to 17th century A.D., agricultural cropping was classifiable using different criteria. Rainy season crops were known as *Mungaru bele.* At present, it is known as *Kharif* crop. These were sown in June /July to coincide with onset of monsoon rains. Post rainy crops (*Hingar bele*) were sown in November and December. A third crop in summer meant use of irrigation. Based on soil resources, farmers classified fields as dry lands (*maru bhoomi*), irrigated arable and wet lands (*niravari pradesha*). Paddy was grown in small, rectangular fields known as *Gadde* that allowed the ponding of water and puddling procedures (Tolbert, 2000; Morrison, 2000).

Major crops grown by Medieval South Indian farmers were:

Cereals: Rice, sugarcane, sorghum, finger millet, pearl millet, and setaria; Grasses (*Paspalum, Panicum*) to feed animals;
Legumes: Pigeonpea, chickpea, lathyrus, green gram, black gram, horse gram, field beans
Oil seeds: Sesamum, castor, groundnut,
Fibre crops: Cotton, and flax
Vegetables: Gourds, pumpkin, cucumber, chilli, tomatoes, egg plant, bhendi etc.
Fruits: Coconuts, mangoes, ber, citrus, custard apple,

Sources: Morrison, 2000; Kotraiah, 1995

Crop diffusions

Several New World crops were introduced into South India during the Vijayanagara period. Maize, chillies, and groundnut may have been introduced to the Southern Indian peninsula between 14 and 17th centuries via Portuguese merchants, officials, or travelers. Groundnuts entered Southern India from Mozambique in South Africa; hence, Southern Indians called them 'Mozambique nuts'. Maize, it seems was brought into South India by European visitors to Vijayanagara, though there is no evidence for the production of maize in or near the city of Vijayanagara itself (Morrison, 2000). Several vegetables originating from Europe and South America are known to have reached South Indian coasts via merchants and Jesuit preachers. There is little doubt that a brisk counter flow of South

Indian crops such as rice, grams, gourds, mango, spices and others ran to ports in East and South Africa and beyond.

Crop Production

Cropping systems followed by medieval South Indians generally depended on access to irrigation facilities and climatic parameters. While wetland yields were relatively high, harvest from dry cropping zones were obviously variable and low (Morrison, 2000). During the Vijayanagara era (14th to 17th century) major wetland crops like rice and sugarcane, as well as coconuts and vegetables, were grown in areas with canal or tank irrigation. *Pan*, made from *Areca catechu* nuts as well as *Piper betel* leaves, was very important in this period and was not only considered an essential part of the meal but was also used in political ceremonies. While Areca palms and betel vines grew easily in the more humid parts of the south, in the dry interior they required the application of irrigation water.

Arable crops or dry crops were grown to coincide with rainfall patterns. Dry land crops included cereals such as sorghum, finger millet, pearl millet and setaria. Legumes included *Vigna species, Phaseolus sp, Lathyrus sativus, Pisum sativum, Dolichos sp* etc. Grasses like *Pasplum* and *Panicum* served to feed the domesticated animals. Cotton was a dominant crop in the Vertisol zones. Its expanses were large, perhaps due to high demand for this fibre crop and the growing commercialization of textile production and trade, a mainstay of South India's international exchange repertoire.

As noted, relatively larger populations in cities and villages meant a greater importance for food production though it should be noted that more extensive forms of production such as shifting cultivation continued to be practiced in some areas and mobile herders and others maintained residence outside of nucleated towns and villages. In the densely settled regions of North Karnataka, expanses of cereals, cereal/legume mixtures and cotton started developing on rich and fertile Vertisols and Alfisols. Indeed, this was the period in which the basic cropping ecosystems or agroecosystems of South India took their form. Crop mixtures and sequences followed by farmers usually matched the limits of soil fertility and irrigation facilities, though the latter allowed a greatly expanded area of cultivation. Agronomic procedures involved both animal and hand operated implements. Soil fertility measures included contour bunding, mulching and manuring with farm refuse. Measures to curtail erosion of soil and water through runoff included gravel mulching and use of a variety of small features such as check-dams and terraces (Morrison, 2000). In the dry regions of North Karnataka, gravel mulching of farmers' fields helped in maintaining soil temperatures more equitable for crop production and reduce evaporation. It seems some of the fields around citadels have been continuously in use since 15th century. Soil erosion control through mulching has been regularly adopted on them for past 5 centuries. Hence, these locations could be used to measure the long-term effects of such gravel mulching on soil and its fertility. Fallowing was also practiced to refurbish the fertility of soils.

During the Vijayanagara era (14th to 17th century), irrigation of crops was mainly achieved via rivers (*Tungabhadra, Krishna*), canals, tanks and ponds, though some irrigation was also achieved using animal-drawn water from wells (Morrison, 2000). In the wetter parts of the south, canals often terminated in storage reservoirs (Ludden, 1985;

Mosse, 2005), a strategy not practiced in Northern Karnataka. Facilities aiding cultivation in this period ranged from very small, informal features such as walls and manure-piles to large, complex systems of canals and reservoirs. Such irrigation facilities were financed by range of elite citizens and large pilgrimage centers such as Tirupati. Where as, reservoirs in the area around the city of Vijayanagara were financed primarily by *nayakas* and other local elites (Morrison and Lycett, 1997; Morrison, 2008). Despite this, reservoirs were closely identified with temples, as is clear from the morphology of Vijayanagara-period sluice gates (Morrison, 2008).

Chibber (1998) argues that there was a marked improvement in cultivation procedures and productivity during Vijayanagara era relative to preceding centuries, pointing to the spatial expansion of arable land noted by historians on the basis of the inscriptional record. While agrarian expansion did indeed take place in punctuated bursts across these centuries (Morrison, 2000), it is in fact not clear if yields rose or cultivation practices improved. Certainly, enthusiasm for wet rice continued to grow, along with the infrastructure required to support this labor-intensive form of cropping. Rice production also expanded, where possible, into the wetter uplands where artificial irrigation was not necessary, a process that partly displaced more extensive forms of farming in those areas (Morrison, 2001). In the Tamil country, rice became a staple cereal grown in rotation with pulses such as *Cajanus* and *Vigna* species (Ludden, 1985). Intercropping became popular, since it provided insurance against crop failures possible with sole crops. Millet plus pulse was a prominent crop mixture in dry areas. As noted, cotton cultivation expanded into the Vertisol zones and riverine zones in North Karnataka and Andhra Pradesh, an expansion closely tied to growing local and international markets for Indian textiles.

The importance of soil fertility to agricultural productivity and farm economics was identified clearly. Inherent soil fertility, the quantity of seed sown and net crop harvest were the major parameters utilized by the Vijayanagara administration while determining productivity. The land revenue system of at least the later Middle period and subsequent Early Modern period was managed by *Kulkarnis* or *Keladi Nayaks*, who kept track of soil fertility and productivity of fields in their jurisdiction and taxed the farmers based on 13 year averages. Farm taxation based on soil productivity was further streamlined and made liberal during 18th century.

4. Modern History of Agriculture in Southern India

4.1. Agricultural History of South India during the 18th and 19th Century

A fierce debate has been waged by historians, about the overall status of agriculture during the 18th and 19th centuries. A debate well illustrated by the title of an edited collection "Growth, Stagnation, or Decline?" (Guha,1992). Certainly one key feature of agricultural production during this period was its growing commercialization, especially with the extension of the railroads. Still, crops had been produced for market at many times in the history of South Indian agriculture (Morrison, 2008), and this factor alone does not necessarily indicate rural distress. This issue is somewhat difficult to resolve using existing historical sources, most of which were generated by colonial rulers with an interest in promoting their own rule as benign relative to those of past rulers.

Most farmers in South India raised crops during at least two seasons. In the Mysore region, a rainy season or first crop was denoted as *Hainu*. It yielded better because of a fairly consistent precipitation pattern. A second crop was called *Caru*. Its productivity depended on stored moisture in the soil and on a few rainfall events. Regarding domesticated animals, both draught and milch breeds of cattle (e.g. Amrithmahal, Halikar), ovines, swine and poultry served the villages satisfactorily.

In the Mysore region, agricultural fields were classified into at least three types based on crops supported by them. They are *wet lands* watered either through copious precipitation or artificially irrigated from tanks or rivers; *dry fields* used predominantly to cultivate arable crops and *bagaich* or garden land. Soils were grouped into different types based on texture, fertility levels and purposes. They are: Black soils (Erray, *Krishna or Mucutu*) containing a predominant clay fraction. These black soils are the most fertile zones in the area; Red soils (*Kempu bumi or Cabbay*) are loamy and support both wet and arable cropping; Sandy soils (*Maralu*) are light brown with large fraction of sand and sometimes a sizeable amount of gravel; Daray is a compact area with sand and gravel not easily manipulated using the plough, often fit only for penning zones and trails. Daray was not used for cropping.

Area demarcated as wetland or irrigated land most often supported the production of rice and sugarcane. In northern Karnataka, around the now-abandoned city of Vijayanagara, commercial production of sugarcane on a large scale began around this time (Morrison, 2000). Wetlands were also put to use for cultivating legumes such as black gram and green gram, sesamum and tadaguny. During the 18th and 19th centuries, rice was a major preoccupation of farmers in Southern India, and continues to be so even today. In southern Karnataka, three different types of rice cultivation were practiced. Direct seeding or dry seeding is called *Bara butta or Puneji*. Sometimes sprouted rice seeds are sown to hasten seedling growth. This practice is called *Mola butta*. A third method popular with farmers in irrigated zones involved transplantation of rice seedlings grown in a nursery for 2-3 weeks, a strategy called *Natti* paddy. Most rice varieties grown during this period required 5 months and some like *Dodda butta* needed as much as 6-7 months (Buchanan, 1807).

Let us consider various agronomic procedures followed by 18th century farmers during rice production. As stated above, southern Indian farmers adopted at least two farming seasons, namely *Hainu* -- a rainy season crop -- and *Caru* that grew during the post-rainy period utilizing stored moisture. The *Hainu* crop of rice is important because of higher productivity. Agronomic procedures like ploughing began during February and lasted until May. Ploughing was repeated at least two times each month. Fields were watered after the fifth ploughing cycle. Rainfall during early seedling period was allowed to drain out, but during later stages it was ponded to allow stagnation. Inundation of fields was continued until crop maturity. Weeding and inter-culture was performed thrice to loosen soils. At maturity, rice fields were drained. The harvested panicles were kept in heaps (*rashy*) of 30 to 40 bushels (Buchanan, 1807). Paddy was stored in clay containers (*woday*). Often, surplus rice grains were stored in *Hagay* (pits) or *Canajas* (store houses). Paddy was processed and utilized as boiled rice (*Cudapal* aki) or fresh rice (*hashy aki*). Farmers in the Mysore dominion grew different types of rice such as *Dodda butta, Hotay Caimbuti, Arsina Caimbuti, Murargili, Puttu butta, Caraculla, Yalic raja* etc. Most of these rice genotypes matured in about 5 to 6 months. They could be grown as *hainu* crop using *mola* or *puneji* systems (Buchanan, 1807). Rice-based cropping patterns were practiced if water resources were satisfactory. Rice monocropping, that is, rice after rice or rice followed by arable crop like *udu, hessaru* or *ellu* was also adopted. In the dry tracts of Kolar, only one crop of dry seeded rice was possible (Buchanan, 1807). Sugarcane was another important wet crop. Mostly, two types of canes were cultivated. *Puttapatti* (striped) types were preferred on *mucutu* or black clayey soils and *Rastalis* were grown on red earth or *cabbay.*

Finger millet (*Eleusine coracana*) locally known as *ragy* in Karnataka, *ragulu* in Andhra Pradesh, and *Kevir* in Tamil Nadu and Kerala was an important dry land crop during the 18th and 19th centuries. At least three different types of *ragy* were cultivated, namely *Cari* (black), *Kempu* (red) and *Hulupuria*. Finger millet was sown with the onset of the monsoon in June or July. The preparatory ploughing generally began in May. Fields were ploughed 5-6 times and farmyard manure applied. Seeds were either broadcast or sown in lines and a thick plank or a harrow known as *halivay* was passed on to smoothen the land. Finger millet was often sown with a legume intercrop such as *Dolichos lablab* (*Avaray*) or *Cajanus cajan* (*Togari*) at a ratio of 1:6 or 1:12 rows. Two types of sorghum (*jola)*, namely, red and white were common in dry tracts of Kolar, Mysore and Coimbatore. It was sown immediately after harvesting first crop of rice. Often, an instrument called *Sudiky* that is a plough-cum-seed planter was used to quickly dibble sorghum seeds into furrows. A sorghum crop ripened in about 3 months. On fertile soils, a sorghum crop was followed by legume such as *kadale* (*Cicer arietinum*). In the dry areas, an admixture of seeds of *shamay, huruli* and *ellu* were broadcast, providing a mixed crop on the field and ensuring against crop failures. Around Bangalore, Channapatnam and Mandya, richer soils supported sugarcane and rice. Dry lands supported rotations of *ragy* and legumes. Sometimes, ragy was not intercropped with the usual legumes such as avaray or togari, but was instead allowed to grow as monocrop. However, immediately after harvest of ragy, a crop of chickpea or sesamum was sown. Monocrops of ragy, sesamum (*hut's ellu*) or shamay (*Panicum*) during both seasons were also common.

During the modern period and later, pigeonpea cultivation was systematic. Seed drills (curigay) were also used. Pigeonpea was intercropped with cereal grain crops such as sorghum or sometimes sown with grasses such as *Panicum miliare* (*Kukti, Shamay*) (Buchanan, 1807; Watt, 1889). Several species of arable crops were cultivated in southern states during the 18th and 19th century, including: pearl millet (chica *cambu*), setaria (*Novanay*), sorghum (*Jola*), black gram (*Udu*), green gram (*Hesaru*), horse gram (*Huruli*), groundnut (*Nela Kadale*), sesamum (*Ellu*) and vegetables. Overall, these crops yielded moderately depending on soil fertility and other inputs (Table 1.2).

In the Mysore and Coimbatore regions, gardening and plantation crops were quite common. Kitchen gardens supported a variety of vegetables such as Badane (egg plant-*Solanum melangina*), Hiray (*Cucumis species*), Cumbala (*Cucurbita pepo*), Padawala (*Trichosanthes lobata*), Benday (*Hybiscus esculentus*) and Gori (*Trigonella tetrapela*). Plantation crops were remunerative. For example, Tengu (coconut), Villadele (betel-leaf), Balay (*Musa* species), Nimbay (Citrus-lime), Kithalay (Citrus-sweet orange), Hayrlay (Citrus-bitter orange), Jambu (*Psidium species*) Hulusu (*Atrocarpus integrifolia*), Nelli (*Phylanthus embelica*), Hunishay (*Tamarindus indica*) and Dalimbay (*Punica granatum*) were frequently grown. Crop production was well integrated with domesticated animals such as cattle, buffalo, oxen, sheep and goats.

In Tamil Nadu, around Sathyamangalam and Coimbatore, dry land cereals such as *Cambu* (Pearl millet), *Sholum* (Holcus Sorghum) and *Shamay* (*Panicum*) yielded 4 to 6 bushels ac^{-1}. Wetland transplanted rice (*Nadavu*) and sprouted seed (*Cai Varupu*), on the other hand, yielded much higher at 40 to 90 bushels ac^{-1}, depending on the season. Rice crops matured in 5-7 months depending on the cultivar sown. A variety called *Caru* required only 3 - 4 months and produced 32 to 48 bushels ac^{-1} (Buchanan, 1807). Major field crops grown in Tamil Nadu during 18^{th} to 19^{th} century, especially in the plains, coastal belt and Cauvery delta were rice, sugarcane, sorghum, cambu (pearl millet) and small millets (*Eleusine coracana*). Cambu was planted on sandy soils because it thrived better there. There were at least two types of cambu sown in Tamil Nadu, namely Natu Cambu and Arsi. Cambu is sown after fields are ploughed 3-4 times and manured with cow dung. Generally, sowing began with the rainy season. Sometimes seeding got deferred until July or even until the end of September in order to ensure that seedlings received sufficient rain water. Cambu is often grown as a mixed crop with legumes such as *Dolichos lablab* or *Dolichos catsjang* (Buchanan, 1807). Rice occupied the greatest portion of the cropping zone in Tamil Nadu, followed by sugarcane, cotton, pulses (pigeonpea, chickpea, green gram, black gram), groundnuts and sesame. Spices such as coriander, chilli and cumin were also cultivated (Parthasarathi, 2006).

Table 1.2 Productivity of Crops grown in Mysore, Coimbatore and adjoining areas in Malabar during 18^{th} and 19th century

Crops	Production (Bushels ac^{-1})	[1] Increase on one seed
Cereals		
Rice under Mola system	31	20
Sugarcane (2420 hills ac^{-1})	10,890 canes	
Ragy (*Eleusine coracana*)	23.35	52
Navanay (*Setaria italica*)	15.56	30
Jola (*Sorghum bicolor*)	15.82	30
Harica (*Paspalum frumentacum*)	15.56	30
Shamay (*Panicum milliacium*)	15.56	30
Legumes		
Avaray (*Dolichos lablab*)	0.889	8
Togari (*Cajanus cajan*)	0.889	8
Huruli (*Macrotyloma biflorus*)	15.56	30
Udu (*Vigna mungo*)	7.0	15
Hessaru (*Vigna radiata*)	7.0	15
Oil seeds and others		
Ellu (*Sesamum indicum*)	3	35
Hut's ellu (*Niger abysinica*)	1.12	10
Wull' Ellu (*Sesamum indicum*)	1.33	12

Source: Buchanan, 1807;
Note: [1] Refers to number of seeds harvested per seed sown.
Measurements used during reign of Tipu Sultan (late 1700) were:
1 seer = 0.607 lb; 16 seers = 1 Colaga; 20 Colagas = 1 Candaca;
1 Candaca or 20 Colagas = 11 bushels. 1.0 bushel = 35.2 litres (dry measure)

In the Malabar region, rice was cultivated on both lowland valley soils (*Ubayum*) and in uplands (*Palealil*). According to Buchanan (1807), farmers in Malabar preferred transplanted paddy in *Ubayum* lands. On *Palealil* locations, sprouted seeds were sown directly. During the 18th and 19th centuries, farmers in Kerala grew several genotypes of rice. For example, *Navara* is a short season crop maturing in 3 months. It yielded up to 30 bushels ac^{-1}. Most other rice cultivars such as *Watun, Calii, Caruma, Ari modun, Cheru Modun* and *Ari Caruma* matured within 4 months. For a seeding rate of 6 bushels, these rice genotypes yielded 32 to 35 bushels ac^{-1}. The *Ubayum* land may have perpetual stagnating water. Hence it was used during only one cropping season. On hilly tracts or *Parumba*, cereals such as Shamay (*Panicum milliare*), *Pyro*-a legume, turmeric and ginger were cultivated. Upland or hill-paddy (*Modun*) was sown on land previously ploughed for at least three to four times. Such a rice crop was sown in July/August. Sesamum followed immediately after harvest of rice. Rice cultivars suited as second crops in the Malabar region were *Maliga or Shiriga Sambau, Shittany, Bally shittany* and *Noman* (Buchanan, 1807). The second crop of rice is almost always transplanted. Obviously, crop rotations followed in Malabar depended on the fertility of soils. On hilly or poor soils, Shamay-Ulindu (black gram)-Pyros were adopted in three-year rotation. A two-year rotation of sesamum-shamay or sesamum-pulse was also common.

Plantations were more frequent in Kerala than in other regions. Most plantations followed multi-storeyed cropping. In the Malabar region, coconut and betelnut plantations allowed understorey cropping. Commonly suited understorey crops were shamay (*Panicum milliare*), sesamum and legumes such as *Vigna* species. Spices such as pepper (*Piper nigrum*) thrived well on lateritic soils. In the Travancore region of southern Kerala, *Parumba* land was used for raising fruit trees like coconut, jack and mangoes and was also used to cultivate hill-rice, shamay and sesamum (Buchanan, 1807).

4. 2. Recent History of South Indian Agriculture (from the early 20th century till date)

During the past 40 to 50 years, an agrarian revolution in South India has resulted in a marked improvement of crop production. Farmers, intermediaries and researchers of various agricultural institutions guided it. Actually, since the early 20th century, several agricultural research institutes, each with a special aim to improve and sustain crop productivity in their jurisdiction were started in South India (Table 1.3). These institutions devised improved practices and guided introduction of several crops and their genotypes. For example, ICAR* institutes and ICRISAT* at Hyderabad in South India, both specialize in maintaining and utilizing germplasm of different cereals and pulses from all over the world. Along with various agricultural universities, they have successfully guided introduction of several useful genotypes of rice, sorghum, finger millet, chickpea, pigeonpea, sunflower, groundnuts, various vegetables and fiber crops. During the second half of the 20th century, crop breeding received great attention. Crop research in most of these institutions aimed at improving yield by exploiting hybrid vigor. They also

* ICAR = Indian Council of Agricultural Research, New Delhi
ICRISAT = International Crops Research Institute for the Semi-arid Tropics, Hyderabad, India

Table 1.3 Chronology of inception of Major Agricultural Education and Research Institutions that guided Agricultural Development in South India since early 1900s.

Year	State / Institution
	KARNATAKA
1899	Imperial Agricultural School, Hebbal, Bangalore
1946	Mysore Agricultural College, Hebbal, Bangalore
1946	Coffee Research Station, Balehonnur, Chickmagalur Dist.rict
1958	National Bureau of Soil Survey, and Land Use Planning, Hebbal, Bangalore
1964	University of Agricultural Sciences, Hebbal, Bangalore
1967	Indian Institute of Horticultural Research, Hessarghatta, Bangalore
1975	Gandhi Krishi Vignana Kendra, Allalasandra, Bangalore
1986	University of Agricultural Sciences, Krishinagar, Dharwad
	ANDHRA PRADESH
1945	Agricultural College, Bapatla
1958	National Research Centre for Sorghum, Hyderabad
1961	Sri Venkateswara Agricultural College, Thirupathi
1964	Andhra Pradesh Agricultural University, Rajendranagar, Hyderabad
1965	Project Directorate on Rice Research, Hyderabad,
1965	Central Research Institute for Dry land Agriculture, Santhoshnagar, Hyderabad
1972	International Crops Research Institute for the Semi-arid Tropics, Patancheru,
1976	National Academy for Agricultural Research Management, Hyderabad
1986	Project Directorate on Oilseed Research, Hyderabad
	TAMIL NADU
1863	Agricultural Experimental Station, Saidapet, Madras
1876	Madras Agricultural College, Saidapet, Madras (shifted to Coimbatore)
1876	Agricultural College, Coimbatore
1964	Agricultural College, Killkum
1965	Agricultural College, Madurai
1971	Tamil Nadu Agricultural University, Coimbatore,
1989	Agricultural College, Kumlur (Trichy) (shifted to Navalur)
1992	Agricultural College, Navalur, Kuttapattu
	KERALA
1955	Agricultural College, Vellayani, Thiruvananthapuram
1963	Central Tuber Crop Research Institute, Srikariyam, Thiruvananthapuram
1970	Central Plantation Crops Research Institute, Kasargod
1971	Kerala Agricultural University, Vellanikara, Thrissur
1976	Indian Institute for Spice Research, Kayamkullum
1994	College of Agriculture, Padannakad, Kasargod
	PONDICHERRY
1966	Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, Pondicherry
	ANDMAN AND NICOBAR ISLANDS
1971	Central Agricultural Research Institute, Portblair, Andman

Note: The above list is not exhaustive but it includes a few important examples. Each of the above South Indian states support several other Agricultural Research Institutions relevant to development of specific Crops, Cropping patterns, Animal husbandry and fisheries.

Source: http://tnau.ac.in/atnau.html; http://uasbng.kar.nic.in/history.asp
http://www.kau.edu/testorg.htm; http://www.uasd.edu/research.htm;
http://www.angrau.net/historicalbackground.htm

incorporated traits that enhanced tolerance to the drought spells common to South India. Simultaneously, crop varieties were imparted with resistance to major diseases and pests. South Indian farmers started using high yielding and improved cultivars of major cereals and pulses. Simultaneously, in mid1900s, use of chemical fertilizers was encouraged by South Indian states. Economic assistance to farmers, too, was made liberal. A combination of congenial factors improved agricultural productivity markedly. This phenomenon was called the 'Green Revolution'. For example, fertilizer-responsive rice varieties such as Jaya, Madhu (MR136) in Karnataka, Hamsa, Thella Hamsa and others in Andhra Pradesh, PTB derivatives in Kerala, ADT series in Tamil Nadu and several others spread into most locations of the rice belt. These genotypes improved grain production by over 20 to 30 % during early 1970s and 1980s. Similar effects were seen in case of sorghum hybrids (e.g. CSH, CSV series) grown in North Karnataka and Andhra Pradesh. This trend of enhanced agriculture productivity using fertilizers, irrigation and hybrids continued further into 1980s and 1990s. During the 1980s, a series of varieties and hybrids of sorghum and millet were developed using African and Indian landraces at ICRISAT and other southern Indian agricultural institutions. These once again helped in stabilizing past yield gains and lessening disease and pests.

During the early 1970s, cross breeding of native Indian and African finger millet (*E. coracana*) by researchers at the University of Agricultural Sciences, Bangalore, resulted in the release of several 'Indaf' varieties that were high yielding and resistant to pests and diseases. Together with irrigation and chemical fertilizer application, these 'Indaf' varieties of finger millet have improved total grain harvests perceptibly during the past 4 to 5 decades in Karnataka. Similarly, Co varieties from Coimbatore improved finger millet production in Tamil Nadu and other parts of South India.

Efforts to improve sugarcane genetic stocks had been initiated earnestly in South India. For example, the earliest cross breeding of sugarcane occurred at Coimbatore around 1912-1919. A South African named Charles Barber crossed native canes of South India with thick or 'noble' canes introduced from Mauritius in 1920 (Wallach, 2005). Since 1960s, a series of 'Co' varieties of sugarcane released to farmers have held sugar production by South Indian states at optimum levels.

The productivity of pulse crops, too, improved during the later half of the 20th century. For example, early maturing, semi-dwarf pigeon pea, improved varieties of *Vigna*, *Phaseolus* and *Dolichos* stabilized pulse harvests. During the past three decades, several high yielding peanut and sunflower varieties were released to improve oil seed production in South India. Groundnut genotypes released or introduced (e.g. Robut 33-1) by ICRISAT in Andhra Pradesh, varieties such as TMV2 in Tamil Nadu, DH series emanating from Dharwar in Karnataka have all sustained groundnut production moderately high at around 2500 kg ha^{-1}. Actually, the productivity of oilseeds improved due to rapid spread of both groundnut and sunflower into the dry lands of South India. Together, these oil seed crops have provided sufficiency in terms of vegetable oil production to South India. Several vegetables were introduced into South India during the 1990s. Many of these are grown in rotation with major cereals and legumes. In the Vertisol belt of North Karnataka and Andhra Pradesh, cultivation of hybrid cottons since 1970s has drastically improved productivity. A more recent trend is the adoption of transgenic cotton (e.g. Bt Cotton). Since the late 1990s, rice hybrids have spread fast into the southern Indian rice belt. The use of pre- and post-emergent herbicides and pesticides has reduced the loss of produce. Cold storage has further improved the availability of food grains and seed material in South India.

During the early 1900s, in the absence of fertilizer-based nutrients, organic farming was a preferred method of raising crops. Chemical fertilizers were only beginning to appear more remunerative to farmers all over India. However, Imperial agriculturists had cautioned that excessive use of fertilizers might bring about deterioration in soils and environment. Despite it, use of chemical fertilizer improved in South India. We may note that, farmyard manure; crop residues and other organics together replenished mere one half of nutrient removed in harvested portions of crops. Hence, in a long run, organics as sole source of nutrients seemed an insufficient technology (Randhawa, 1983; Wood, 2002).

Chemical fertilizers have played a key role in improving crop production in South India. The improvement of crop productivity in South India resulting due to inorganic fertilizers is comparable to those achieved in other parts of the world. Fertilizer consumption actually increased several fold between the 1960s and 1980s, perhaps 9 to 10 fold over levels known during mid-1900s. Obviously, large quantity of nutrients was injected into Southern Indian agroecosystems in order to attain high crop yields. Therefore, several aspects of nutrient dynamics were influenced conspicuously. Firstly, fertility status of soils improved resulting in higher crop productivity. However, in some places, deterioration of soils and general environment was also visible due to excessive accumulation of chemicals in ground water and irrigation ducts. Soil salinity got accentuated in some areas of North Karnataka (e.g. Thungabadhra Project Area). Nutrient imbalances were also created leading to stagnation of crop harvests. Soil deterioration also meant change in cropping patterns. Further, farmers dependent on chemical fertilizers and other commercially available inputs are much more vulnerable to changes in prices and market conditions, sometimes with disastrous consequences.

Mechanization and automation of farm activities was feeble until the mid 1900s. Hand-held implements and animal traction were most common and remain important even today. However, since the 1960s, specialized equipments such as power tillers, tractors and even combine harvesters were rapidly introduced into South Indian farms. Per capita availability of agricultural machinery increased markedly during the second half of the 20th century, indicating rapid mechanization of agriculture in South India. Most dramatically, rural electrification vastly changed the nature of irrigation in South India. In areas where dry farming and reservoir irrigation once dominated, deep bore wells with electric pump-sets are becoming common, allowing production of an entirely different suite of crops. Conversely, water tables in many of these areas have dropped dramatically as a result of this change. Many of the post harvest operations were also mechanized, and there is now a tendency to introduce electronic systems into farming in as many facets as possible. Computer models are being utilized to forecast weather, devise and decide on fertilizer and irrigation schedules; control water disbursement in fields; regulate pesticide application; harvest, process them and to market the produce.

5. Historical Aspects of the Evolution and Use of Agricultural Implements in South India

During the Paleolithic periods, prior to invention of agriculture, South Indians and others on the subcontinent, utilized stone tools such as choppers, polyhedrons, hand axes, cleavers, scrapers, denticulates and blades. These tools were used for hunting and the processing of animals and also for the gathering and processing of wild plants. Implements such as unifacial and bifacial choppers, flake blades, and discoids were excavated from Paleolithic sites at Chingelput, Naiveli, Dharmapuri and Kuttampalli (Ramachandran, 1980). For the most part, human populations were highly mobile (Misra, 2001; Paddayya et al. 2002).

Mesolithic groups, too, practiced hunting and gathering, but more stable coastal settlements based on fishing are also known. Mesolithic tools were often sophisticated complex tools, made by hafting a series of small-sized chipped implements known as microliths. These hafted tools included sickles, knives, and would have been important for cutting and processing plants. Microliths are classically made on blades—long, straight-sided flakes. Common forms include backed blades, obliquely truncated blades, crescents, triangles, trapezoids, and lunates. Microliths continued to be made and used well after the Mesolithic (Morrison, 1999).

The Neolithic across the world is often marked by the presence of new tool forms, especially ground stone tools. The ground stone axes, hoes, and food processing tools such as querns, mullers, and rubbers represent widespread solutions to common problems faced by peoples increasingly dependent on the collection, and eventually cultivation of plant foods. South India is no exception to this pattern. The Southern Neolithic, once called the "Stone Axe Culture" (Wheeler, 1947) for its ground stone axes, was the time when chipped stone tool forms of the Mesolithic continued to be used, but when many new forms appeared, especially hoes, adzes, wedges and chisels (Misra, 2001). These new tool types would have been important for soil preparation, seed dibbling, and inter-culturing (Southworth, 2006), while the existing hafted-blade tools would have been better-suited to and harvesting panicles. Grinding of both cultivated and wild plants clearly took a great deal of time and household labor; wild plants continued to be an important part of local diets even into the Iron Age and Early Historic periods.

Southworth (2006) made a comparative study of archaeological findings and linguistic descriptions related to Southern Neolithic sites in North Karnataka and Andhra Pradesh, arguing that there is no evidence for development or use of plough during the Neolithic period. He suggests that linguistic data indicate some form of land preparation that is primitive/ancestral to ploughing. However, evidence from the bones of cattle found in Neolithic sites (Allchin, 1963) suggests that they were used for traction or some other heavy labor that would have produced stress on the joints. There is thus some chance that ploughs were already in use at this time though these would have used stone and wood exclusively, if they were present.

The invention and use of the plough is an important event in agricultural history. At the Harappan site of Kalibangan in northern India, excavations revealed the existence of a well-preserved ploughed field dating to the second millennium B.C. Given that agriculture intensified in southern India during the Iron Age, when large nucleated settlements were established, it is also probable that greater attention was paid to soil preparation, especially as crop repertoires were also being revised. Ploughing would have allowed ancient farmers to dig, invert, mix and freshen up soil effectively before sowing seeds. Secondly, ancient farmers may have perceived improvements in planting geometry; plant density and uniformity of crop stand obtainable through a line-sown crop. Thirdly, a line-sown crop must have meant clear advantages during inter culture, irrigation, manuring and harvesting. Uniform and well-spaced crops may also have improved exploitation of soil fertility (nutrients) and moisture more efficiently.

Introduction of iron technology added efficiency to farming practices. At the site of Kadebakele in northern Karnataka, faunal evidence from the early Iron Age, around 800 B.C. (Bauer, 2007), clearly shows the use of cattle for traction, almost certainly evidence for the use of the plough. At this site, iron is also common, though nothing clearly identified as a ploughshare can be detected. In general, the use of iron for tools during the Iron Age of South India was widespread, though stone tools continued to be used for some purposes. Wooden ploughs would have been tipped with ploughshares made of iron and iron axes and knives were helpful in clearing patches of jungle in order to initiate agricultural cropping (Misra, 2001; Satyanarayana, 1999). Rock-cut water storage features may also have been enlarged using iron tools (Bauer and Morrison in press).

Excavations of sites from the Iron Age and into the medieval periods have yielded remnants of ploughs and plough shares (*phal*). According Kautilya's(321-296 B.C.) *Arthashastra*, ploughs, known as *Karshanayantra,* were built by a group of persons such as blacksmiths, carpenters and rope makers. Patanjali's(200 B.C.) *Mahabashya* states that fields to be used for farming are usually cleared of stones, thorns, unwanted shrubs and weeds. The specific implement utilized to perform these activities differs. Fields were ploughed using ox (*goh*) driven ploughs. Soil clods, stumps and weeds were cleared using a hoe known as *'Stambaghna'*. Excavation of settlements and burial structures such as Toppikal (cap stones), Kuttakal (umbrella stones) and Kallara (laterite caves) belonging to the megalithic culture of Kerala have revealed the use of several types of agricultural implements, including shovels, hoes, adzes and ploughshares (Cherian, 2001).

Sangam literature from Tamil Nadu, dated to between the 2nd century B.C. and the 2nd Century A.D., depicts use of wooden ploughs and iron implements for various agricultural activities. Artifacts and remains of implements like iron ploughshares, spades, inter culture and weeding devices have been traced in locations from Tamil Nadu. Deep ploughing was achieved using a buffalo-drawn large plough. Agricultural implements were traced at several Iron Age sites in Tamil Nadu. These include iron hoes and ploughshares used to plough and prepare land, as well as flat axes, cross band fasteners, and sickles to cut trees (Ramachandhran, 1980). A tool called 'Sanyam' was used by Southern Indians to harvest paddy. Implements for water management during paddy cultivation included *yettam and keilar, amiry.* These helped farmers in drawing water from wells, tanks and rivers.

Nomenclature of Plough in Southern Indian languages: *Langal, hala or sira* in Sanskrit (Rgvedic literature), *Negal* in Kannada, *Nagali* in Telugu, *Nencil* in Tamil, Njengol in Malayalam, *Nengi* in Kudagu, Neyeru in Tulu, *Nengil* in Godi, *Nangar* or *Nangli* in Naiki, *Nangal* in Gadaba, (Nair, 2001). Etymologically 'nam' means oxen and 'kol' refers to staff or a stick— so, nam-kol is ox driven stick. *Sira* is a large heavy plough

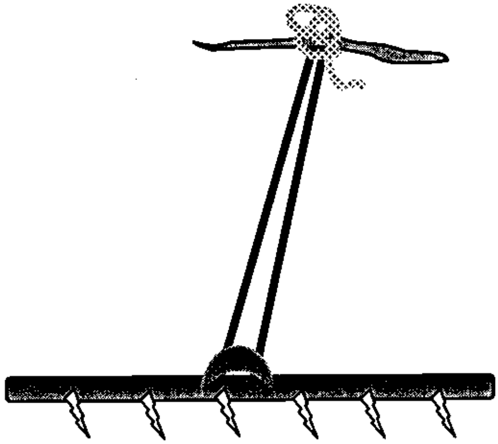
As noted, during the middle periods, southern farmers cultivated a diverse assemblage of crops. Among them, rice and sugarcane were important wetland crops. Sorghum, finger millet, pulses, cotton and oil seeds were arable or dry land crops. These crops needed specific implements for land tillage; inter culture, harvest and post-harvest processing. Fertile lands were generally tilled using ox-drawn ploughs. Tolbert (2000) recorded modern tools that might have also been used in the past, including pick axes (*kodali*), hoeing adzes (*mummti*), weeding adzes, weeding devices (*varvari*) (Plate 1.1), and sickles (*macchu*) to peel coconut and cut plantain. The *Mammotti* was used consistently during Medeival times in the Thanjavur rice belt. It helped farmers in digging, leveling and shifting soil from one place to another in fields. Planks were later used to level the field before puddling and transplanting.

Agricultural implements used during the 18th and 19th centuries were mostly hand-operated or animal- drawn. Ploughs of different sizes and modifications to suit the land and location were available (Plate 1.1). Ploughing was practiced several times during a year before the crop was sown. Deep ploughing was done with heavy wooden ploughs fitted with iron shears. Seeds were either broadcast or line sown after passing a furrow maker with spikes. Harrows and hoes of different sizes were made to suit the purpose; these were mostly ox-drawn. The *Halivay* or harrow is a large bullock-drawn rake. It is passed over land after seeding. The *Cuntay* or bullock-drawn hoe is used after legumes such as *Avaray* or *Togari* are sown. The *Cuntay* helps in attaining regular rows of crop (Plate 1.1). In Kerala, dry seeded rice was sown after several times of ploughing using large ploughs. Sometimes, for *navara* rice, land is ploughed 10 or more times with a country plough. Soils are manured and then smoothened using *Uricha maram*, a two ox-drawn yoked implement. After sowing with sprouted seeds (*mola vittu)*, land was smoothened using an ox-drawn plank or hoe called *Parambu*. In the Malabar region, farmers consistently used small hand-held implements such as *padana caicota* or *haray* of different shapes. A pick-axe known as *Malagi* was used to dig channels around cropping zones.

Weeding was accomplished using a small iron instrument known as *Ujari*. *Warvary* is a simple hand-held implement common to most southern Indian farms of 18th and 19th centuries. Itis perhaps most common instrument used by South Indian farm laborers even today. It has a small iron blade held in place by a wooden handle. It is convenient for weeding dry fields of ragi, cambu, avaray or other legumes (Plate 1.1).

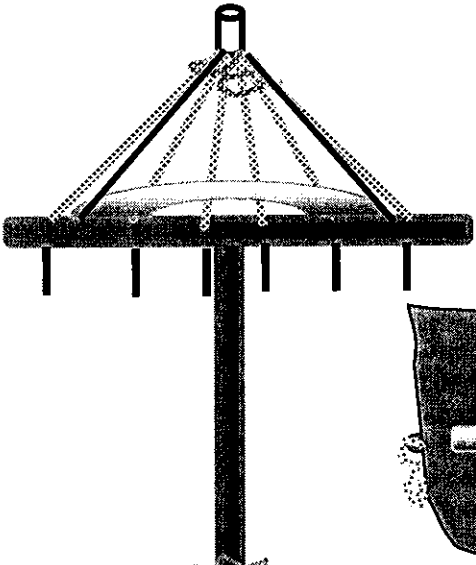
Panicles of paddy were reaped using sickles known as *Cudagolu* or *Cudagu*. Actually, several types of sickles to suit specific purposes such as harvesting cereals, legumes, sugarcane, and plantation crops like coconut were being used by farmers during the 18th century. Many of them are still in use.

Since the mid 1900s, mechanization has been rapid on South Indian farms. Per capita utilization of farm machinery such as tractors, power tillers, implements, sprayers, irrigation pumpsets, harvesters, threshers and seed processors has increased remarkably. During the past decade, electronic controls and farm gadgetry have further improved crop management. Computers and simulations are being used to arrive at the most appropriate decisions, especially regarding crops, their genotype, fertilizer and irrigation schedules, harvesting and marketing.

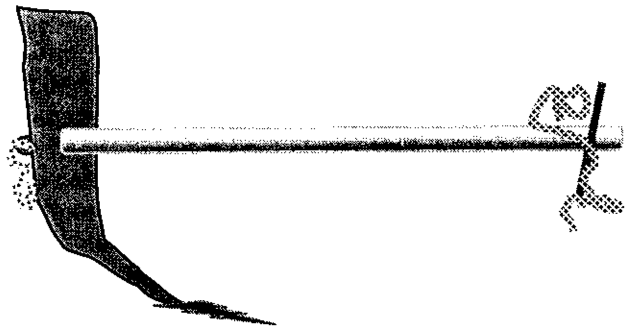


Toothed Harrow or Cuntay
Wooden harrow with metal spikes

Varvari
Wooden hand-held weeder with replaceable metal blade or chisel



18th century Seed Drill (Curigay)
Bamboo conduits allow simultaneous release of seeds into multiple furrows



Wooden Plough with share

Plate 1.1 Diagrammatic depictions of Agricultural implements used by South Indian Farmers, during 18-19th century. Note: *Halivay or Cuntay* is used during line sowing of cereals or legumes. It helps in formation of light furrows and covering soils over seeds. *Varvari* is a common weeding instrement used in South India since medieval times. It still continues to be most handy instrement with farmers. It is used to weed hard soil surfaces common in dry land zones. *Seed Drill,* an indigenous seed drill prepared using bamboo cylinders, wooden bars and metal coulters. It allowed farmers to sow seeds in multiple furrows and achieve efficiency. Compare it with currently used electronically controlled planter on page 202, chapter 4.

6. Agroclimate, Water Resources and Soils in South India: Historical Descriptions

6.1. Agroclimate and Soils

Misra (2001) believes that Neolithic South Indians, especially those in Northern Karnataka, Andhra Pradesh and parts of Tamil Nadu, tailored agricultural practices and selected crops that suited the prevailing semi-arid environments. In general, semi-arid climates are characterized by warm temperatures, erratic precipitation patterns and annual rainfall ranging from 500 mm to 1200 mm. Efficient utilization of precipitation depended on location and topography, as well as soil and water management procedures adopted by Neolithic dwellers. Crops better adapted to semi-arid climates such as millets, sorghum and hardy legumes like *Dolichos* and *Vigna* species were thus preferred. There is clear evidence of the cultivation of both rainy season crops (rice, millets, pulses) and those suited to winter (wheat and barley) during the Southern Neolithic. Obviously, there was a semblance of knowledge about agricultural seasons and crops that suit each of them.

Later, in ancient India, seasons were meticulously marked. Crops were classified based on season during which they were sown, raised and harvested. Winter crops were known as *Haimana* and summer crops *Graishmika*. Crops such as rice, vegetables and pulses were selected based on season and water resources. Wet crops known as *Kedara* were grown depending on water resources. Seasons (*ritu*) known to agriculturalists in South India during the 1st millennium B.C. are still in vogue among native communities in India. A single season (*ritu*) spans almost 2 months of the present-day western calendar. In all, there are six seasons. They are *Sravana* and *Proshthapada* are the two months that make up the rainy season, called *Varsha*. Asvayuja and *Karthika* months make up the autumn, called *Sharad* ritu. *Margsirsha* and *Pausha* make up the winter, known as *Hemanta*. *Magha* and *Phalguna* make up the dewy season, known as *Sisira*. *Chiathra* and *Vaisaka* make up the spring, called *Vasantha*.

Written evidence suggests that during the Early Historic, and perhaps before, Indians relied on the Hindu Almanac called '*Panchanga*' to forecast seasons, rainfall, temperature and other agroclimatic parameters. Panchanga adopts five different parameters, namely *thithi* (lunar day), *vara* (week day), *nakshathra* (star on the horizon), *yoga* (movement of sun) and *karana* (lunar aspects) to develop probable ideas on the weather.

In the Sanskrit literature there are indeed innumerable references to agricultural practices relevant to raising crops. There are detailed methods to ascertain annual rainfall and its impact on cropping. Cropping activity was to be generally matched with calendars prepared on the basis of celestial movements. According to Varahamihira's Brihatsamhita (350-400 A.D.), clouds were classified into four types, namely *Avartaka, Sambartka, Puskara* and *Drona*. The effects of each of these cloud types on cropping differed (Bhat, 1981; Ramadas, 2002). *Avartaka* produced scattered rainfall. *Sambartaka* resulted in more uniform precipitation across locations. *Puskara* caused only low amounts of precipitation, whereas *Drona* meant higher amount of rain. The extent of precipitation was actually measured and quantified using a unit called *Adhaka* (Krishiparasara, 950 A.D.; Varahamihira, 350-400 A.D.) (Sadhale,1999; Bhat, 1981). Rainfall was also measured in *Pallas* using appropriate circular vessels. Fifty *pallas* made one *adhaka* of precipitation. During this period, one of the primary suggestions to farmers was that if it rains thrice, with cloudy sky and no sunshine, then land would be fit for working with plough. Incessant rains for three days ensured soil moisture sufficient for seeds to germinate and seedlings to sustain initial growth.

Despite a long history of construction and use of irrigation facilities in the south, rain-fed agriculture was always the most common form of cropping in all periods. During the Iron Age and Early Historic periods, farmers were prone to select field locations with relatively wet or swampy fertile soils, especially locations near ponds, lakes and river bends that were most likely to support a good crop of rice, millet and/or pulses. Agricultural calendars used during the Early Historic mention that seeds of cereals and legumes such as pigeonpea should be sown immediately with the onset of seasonal rains (Nene, 2006). Sowing seeds immediately with the onset of monsoon would ensure better use of total precipitation received during the entire season. Kautilya (321-296 B.C.) notes that pulses such as chickpeas were grown as rain-fed crops. Legumes were not generally provided irrigation (Ayachit, 2002; Nene, 2006).

Pathanjali's (200 B.C.) *Mahabashya* states that crops were generally matched to water resources and soil type. While cultivating rice, water needs for transplantation and seedling growth was met from tanks for the most part, a situation clearly possible only in wetter environments. Further, next to sowing, watering fields was most crucial factor that determined crop produce (Nigam, 1975). Watering was possible through both natural and artificial methods. Because the region discussed in this text generally received rains during two periods in a year, two crops were cultivated in a year. Kautilya's *Arthashastra* discusses the quantity of water required to grow specific crops, clearly identifying the variation in quantity and pattern of precipitation received in a specific agricultural zone. It states that, in a season, 33% of precipitation could be received during the first few weeks of cropping season and the final 66% during the mid season and closing months. As stated earlier, crude measures of rain and even rain gauges that gave a rough estimate of precipitation might have been in use at this time.

During the medieval and later eras, crop seasons were matched as accurately as possible with prevailing agroclimate. For example, during the 17th to 19th centuries, rice dominated agricultural expanses in the wetter parts of Tamil Nadu, a pattern continuing even today. Around the rice belt of Thanjavur and the plains, the agricultural calendar in medieval times began a few weeks ahead of the monsoon. A pre-monsoon ploughing and light preparation was carried out around April. Manuring was done between April and June, allowing sufficient time for organic matter to decompose and release nutrients. Fields were ploughed repeatedly during July and August. Rice seedlings kept ready in nurseries were transplanted into the main fields in September, with crop duration lasting until the end of December or early January. Harvesting would be complete by February (Rajagopal, 1942; Parthasarathi, 2006). Sometimes, rice/legumes were sown in October and harvested by March. Double cropping meant that farmers in Tamil Nadu were kept busy for 8 months in a year, whereas single cropping required their attention for only 5 months (Ludden, 1985).

During the 18th and 19th centuries, farmers cultivated crops during two distinct seasons; a rainy season crop called *Hainu* and a post rainy one known as *Caru*. Rice was grown both during *Hainu* and *Caru*. In the case of rice, a crop season extended for 5-6 months and sometimes 7 months, depending on genotype. For example, a *dodda butta* crop may need 7 months. Crop seasons, the timing of agronomic procedures and harvest dates were well stabilized for most species grown in South India (Buchanan, 1807). Farm operations were mostly guided by predictions about the immediate agroclimate and suggestions available in the Hindu almanac - *Panchanga*. Currently, meteorological forecasts, farm bulletins and the irrigation resources of farmers guide the timing of agronomic procedures.

Since the 1960s, early maturing semi-dwarf rice and short-season legumes have occupied most South Indian cropping zones, allowing two or even three crops annually. Currently, the major crop seasons in South India are *kharif* (rainy season) that lasts from June/July until October/November coinciding with southwest monsoon, and *rabi*, the second season or post rainy crop. The *rabi* crop thrives predominantly on stored moisture in soil plus a few irrigations, if available. A third crop during the summer is possible in locations endowed with sumptuous water resources. For example, in some parts of Kerala, three crops are raised in a year, namely *Viruppu*, *Mundaka* and *Punja*. Often a major cereal such as rice is grown during *kharif*, followed by either rice again or a dry legume or oil seed, followed by short crop of green manure. Fallows are also common, especially after two seasons of cropping.

6. 2. History of Irrigation and Water Management in South India

According to Fuller et al. (2004), winter crops such as wheat and barley were found in the Neolithic sites of North Karnataka, suggesting that some form of irrigation, perhaps tank-based, was utilized by Neolithic population of South India (Kajale, 1988; Fuller et al. 2004). Extensive study of sites and landscapes of the Southern Neolithic have, however, yielded no definite evidence for such facilities. The fact that these crops only occur in very small quantities may suggest that they were grown in kitchen gardens or under pot-irrigation rather than in extensive fields. This is not to say, however, that Southern Neolithic peoples did not actively manage water and soil. Indeed, the location of many Neolithic settlements on or at the bases of the high granitic hills in northern Karnataka suggests an interest in water harvesting (Morrison, 2008). Terraces, some of which were used for residence, may also have served as soil and water control features. While reservoirs or tanks may have been used, in all cases these are located near later Iron Age and Early Historic sites and are not yet clearly distinguishable from facilities of these periods.

Irrigation was clearly practiced by agriculturalists in South India during the Iron Age, with well-dated examples of reservoirs (tanks) by 800 B.C. (Bauer and Morrison in press). With the expansion of rice culture and the need to supply food for large settlements, there was a critical need to improved and secure crop production. Ancient southern Indian literature provides evidence for the existence of agricultural canals (*Kulya*), wells (*kupa*), water from excavation of the ground (*Khanitrima*) and artificial streams (*kritrima-nadiya*). Irrigation facilities were taxed. A part of the produce, say one fifth was to be recovered, if irrigation canals were utilized. Knowledge of seasons, precipitation pattern and methods to quantify precipitation were also used. Ancient Kannada (prakrit script) literature such as *Ghatasapthasati* provides evidence suggesting that water resources were actually classified as those from rain (*Deva mathrika*), from rivers (*Nadi matrika*) and from tanks (*tataka*) (Parameshwara Bhatta, 1966). There are several references to the construction of dams, canals and irrigation channels to secure water from the Kaveri River and its tributaries. Sangam literature from the 1st century A.D. asserts that agriculture flourished under Chola kings, attributable to the development of embankments, canals and channels from the Kaveri River. Considering the rich soils of the Kaveri valley and delta, soil fertility and irrigation together must have facilitated relatively high crop yields in the southern part of the peninsula.

Pallava inscriptions dating to between the 5th and 7th centuries A.D. suggest that tank irrigation was popular with agriculturists, as was water diverted from rivers such as the *Vegavathi* and *Palar*. Inundation canals helped in utilizing excess water that collected in tanks and embankments (Kotraiah, 1995). It is worth noting that the attention of the inscriptional record to irrigation reflects the interests of king, local rulers, and other elites in agricultural expansion and intensification, not only because of the enhanced revenue involved, but also because of the religious merit and political prestige associated with the patronage of irrigation (Morrison, 2000; 2008). Thus, southern Indian dynasties from at least the 8th century A.D. onwards encouraged formation of tanks, ponds, and canals. In favorable environments and years, tanks supported cultivation of wetland rice and other water-loving crops. In other contexts, reservoir water was used to make dry cultivation more secure.

Archaeological evidence from near Tiruchirapalli in Tamil Nadu indicates the use of *jala yantra*, a kind of Persian wheel that helped lift water and distribute it to crops. Earthenware vessels may have been used in lift irrigation known as *etadama or etapulam*, which would have supported summer crops. Structural remains and textual evidence (Ludden, 1985) from the 1st millennium A.D. suggest that irrigation systems in Tamil Nadu were well-established parts of agricultural practice. Cholas and Pandyans reigning around 10th to 12th century A.D. classified irrigation facilities as *Anai* (small dam), *Korumbu* (partial or temporary dam), *kal or kalvai or vayakkal* (canal) etc. Several types of lifting devices were used known as *karambi, kilar, puttil, puttai, iraikudai or eram* (Kotraiah, 1995). A historical list of irrigation facilities used in Tamil Nadu from the first through 10th century A.D. is available (Krishna, 1966). Even in the drier parts of northern Karnataka, river-fed canals were used on a small scale by the 9th century, although the dominant form of irrigation between about A.D. 900 and 1300 in this region was the informal diversion of small seasonal streams (Morrison, 2008).

Irrigation in Medieval South India

Notwithstanding the critical importance of dry farming, which hardly appears in the written record at all, historical sources from the medieval periods betray a preoccupation with irrigation (Morrison, 2008). In fact, there was a great expansion in the number and variety of irrigation facilities during this time. Although the spatial expansion of agriculture at the expense of more extensive forms of land use such as herding, foraging, and the like was a constant pattern from at least the 10th century A.D., during the Vijayanagara period, the tempo of investment in reservoirs, canals, and other kinds of irrigation facilities seems to have increased significantly. This is certainly clear for the area around the city of Vijayanagara, but the patterns seems to have been much more widespread, with the extension of cropping across the kingdom evident from the historical record and limited archaeological evidence (Morrison, 2008; Morrison and Lycett, 1997; Plate 1.2). Reservoir

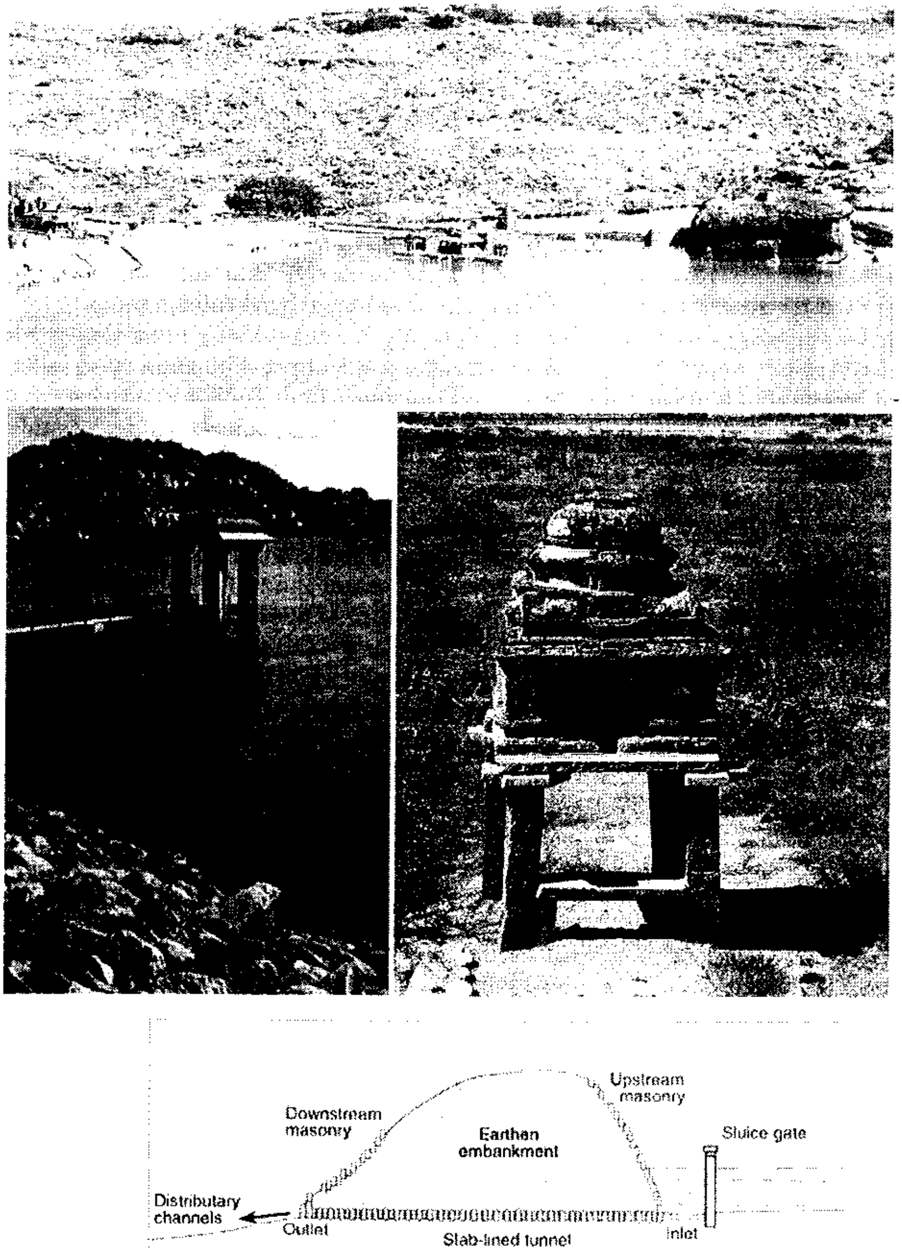


Plate 1.2 Top: A reservoir in North Karnataka (Badami) belonging to Pulikeshin period (5 th century A.D.) that served multiple purposes including irrigating crops. Middle Left: The northern sluice of the Daroji reservoir of 16th century Vijayanagara. Middle Right: A sluice gate on a lake bed at Korugodu, near Hampi. Bottom: A cross section of reservoirs used around Vijayanagara during Medieval Period 14-17th century A.D. (Photo by Professor Kathleen D. Morrison, University of Chicago).

(tank) building and, in places, canal construction, in the drier tracts of Karnataka, Andhra Pradesh and Tamil Nadu reached their zenith between the 13th and early 16th centuries (Kotraiah, 1995; Morrison, 2000), though there were consistent efforts in later periods to maintain at least some of these facilities.

Irrigation canals and their maintenance received prime attention among the medieval South Indian kingdoms. There are several archaeological remains as well as inscriptions dating from 1350s to 1450s proving that Saluva kings of Vijayanagara paid special attention to development of agricultural canals (Kotaraiah, 1995; Morrison, 2000). Several types of sluices were used to regulate water flow to farming communities (Kotraiah 1995; Morrison, 2000; Davidson-Jenkins, 1997). Information on regulation of sluices is available in inscriptions and writings belonging to Vijayanagara period. Inscriptions in Kannada language such as *tubu* (sluice), *hiriya tubu* (main sluice) naduvana-*tubu* (middle level sluice) and those in Telugu language such as *pedda-kaluva* (big canal) relates to regulation of water resources. Escape weirs or waste weirs were built to store surplus water. Similarly, in the Tamil region of South India, medieval farmers during the reign of Cholas, regulated flow of tank water to agricultural fields using sluices. These sluices are called *peri madai* (big sluice), *siru madai* (small sluice) and *kadai-madai* (last sluice). Interestingly, most of the Vijayanagara-period canals around the capital city are still in use today, having never been abandoned.

Irrigation tanks were built to suit the location, size of agricultural area and population thriving in that area. Both river-fed and rain-fed tanks were utilized to irrigate crops, though river-fed canals are much more common in Tamil Nadu, with only two ever built near the city of Vijayanagara. There are still many tanks currently in operation in this region of South India that were built 500 years ago; the vast majority of them, however, lie abandoned. Textual sources indicate that irrigation tanks were called by various names such as *kere, katte, kumte, kola, kolam, samudra, sarovara, eri, thataka, theertha, madaga* etc. (Kotraiah, 1995).

Rain-fed cropping was extensive in medieval Southern India. We should note that South Indian rivers and their tributaries are all seasonal, unlike in upper India. Medieval farmers practiced ground water exploitation through wells and spring wells. Two types of wells were prepared, permanent wells with replenishments of water from subsoil strata and temporary types dug into river beds. Again, there are innumerable wells dating to 14th and 17th century that are still in use. Several archaeological remains and inscriptions regarding construction of wells to augment agriculture in South India are available (Kotraiah, 1995; Morrison, 2008).

During the 18th and 19th centuries, southern Indian monarchs continued to benefit from established irrigation potential. Tanks, canals and river-based systems supported the production of rice, sugarcane, legumes and arable crops. Numerous reservoirs and lakes supported cropping during the post-rainy season. According to Wallach (2005), the transformation of the agricultural landscape during the modern period (1700 -1900) of the history of South India is partly attributable to irrigation facilities. During British rule, agricultural cropping in selected regions expanded into areas otherwise left fallow or used only for rain-fed cropping. Cropping intensity too improved, since irrigation allowed double cropping. Wetland crops like rice or sugarcane were alternated with arable ones. Two crops per year became a possibility in areas irrigated using tanks or small dams on rivers. In fact, irrigation induced the formation of agroecosystems based either on mono-cropping or inter-crops. Overall, irrigation had definite influence on cropping patterns and development of agroecosystems in South India. For example, the riverine zones of the Cauvery, Krishna and Tungabhadra Rivers gave birth to wetland rice and sugarcane ecosystems, whereas, the rain-fed belt (without irrigation), supported dry land cropping ecosystems based primarily on crops such as cotton, sorghum, finger millet, pigeonpea, groundnut, cowpea etc.

Irrigation facilities of more recent times, from the 1900s onwards, are once again classifiable into ground water, pond or tank irrigation, small and large dams and their canals etc. Since the 1900s, several minor and major irrigation projects have been established in Southern India, providing water to large areas previously without perennial irrigation. Indeed, the construction of several large river-based irrigation projects in South India during the 20th century was responsible for a major expansion of irrigated cropping, much of it for commercial crops. For example, the development of the rice belt in Andhra Pradesh is attributable to major irrigation projects on the rivers Krishna and Godavari. Similarly, dams across river Kaveri have induced formation of highly productive rice agroecosystem in Karnataka and Tamil Nadu. Currently, rice agroecosystems in South India extend across into 8.5 m ha. Dams across the rivers Ghattaprabha, Mallaprabha, Bhima, Tungabhadra and Krishna sustain the dry cropping ecosystems that produce sorghum, pulses, cotton and chilli in North Karnataka, though some of this may be threatened by siltation in these large dams and their subsequent decline in capacity. We may note that historically water resources have been a key to development and sustenance of an agroecosystem. Alterations in water availability can change the pattern, expanse and intensity of cropping, ultimately affecting the whole agroecosystem. Water use efficiency is a major concern to farmers in drought-prone regions. Rapid advancements in methods of irrigation have improved water use efficiency. During recent years, high-input farms have adopted irrigation based on canals, furrows, sprinklers and even drip systems.

6. 3. Soil Fertility and Productivity of Crops in South India: Historical Aspects

The major soil types encountered around Neolithic sites of Southern India are Alfisols, Vertisols and Lateritic. Vertisols are common in North Karnataka and Andhra Pradesh. They are mostly rich in montmorillonite clay fraction, and are characterized by a good buffering capacity for both water and nutrients. Alfisols (red loamy) are encountered in most parts of Andhra Pradesh, Karnataka and Tamil Nadu. These are used to cultivate arable and drought tolerant crops. Coastal soils are relatively rich in sand. In Kerala and western Karnataka, soils are predominantly lateritic, rich in Al and Fe silicates, but deficient in many other nutrients that get leached out due to incessant rains. These soils are being used to cultivate plantation crops, rice, pulses and several types of vegetables.

Knowledge about soils and their fertility were important to ancient farmers in South India. Ancient farmers in Kerala and Tamil Nadu classified their areas based on soil types and ecozone. They demarcated them based on soil fertility and cropping pattern into *Kurinji* (parched land), *Marutum* (fertile land) and *Neital* (littoral land) (Cherian, 2001). There are several mentions of the use of organic fertilizers to improve crop growth and productivity. A study of *Vriksayurveda* (Sadhale, 2000) suggests that animal manure, cow dung and farm yard manure (FYM) prepared by mixing crop residues were used during the pre-modern periods; archaeological evidence from the Vijayanagara period (Morrison, 2000) also indicates the use of farm yard manure on dry fields near villages. According to both, Surapala's (1000 A.D.) *Vriksayurveda* and Sarangahara's (1300 A.D.) *Upavanavinoda*, a liquid fertilizer formulation known as *Kunapjala*, perhaps made of decoction from organic manure, was once in vogue (Ramabai, 2002; Sadhale, 2000).

Manuring was practiced regularly during the ancient period. Kautilya's (321-296 B.C.) *Arthashastra* states that seeds were treated with manure prior to planting. Perhaps a small amount of organic manure meant, priming seedlings at very early stages of growth. Seed treatment measures differed according to crop and could extend from 3 to 7 days. A good preparation of FYM or organic manure contained cow dung, hog fats, crop residues, butter etc. Sometimes, manures contained minute fishes, sprouted seeds, roots of trees and burnt bones. (Nigam, 1975). Obviously, compost and its positive influence on soil fertility and crop growth were well understood by farmers.

During the 18th and 19th centuries, southern Indians grew a large number crop species. The preferred soil types, cropping pattern, rotations, agronomic procedures, harvest dates and post harvest processing were highly standardized. Depending on the region, sizeable portions of cropping areas were provided irrigation from artificial sources. Inherent soil fertility and manuring procedures, along with water availability, played an important role in determining yield levels. In Southern Karnataka and adjoining areas of Tamil Nadu, highly fertile soils were generally allocated to rice and sugarcane. Soils were classified and utilized based on fertility. Usually, fertile fields called *Erray or Mucutu* were allocated to rice or sugarcane. *Cabbay or Kempu bhumi* (red soils) that are relatively less fertile were utilized to raise finger millet (ragy), pearl millet (cambu), sorghum (jola), arable legumes, oil seeds and other species.

In Kerala, *Ubayum* or fertile low lands were allocated to rice and were ploughed several times. Manuring was adopted 2 to 3 times in a year to replenish fertility. Most commonly, farmers first collected bushes and other vegetation, and burnt them to improve soil nutrient status. Often, a mixture of ash, cow dung, dry leaves, bushes and cut portions of trees went into making manure (Buchanan, 1807). Manuring dry seeded or sprouted seeded crops produced 35 to 40 bushels of paddy.

It is difficult to obtain accurate estimates of productivity of pigeonpea and other legumes grown by early agriculturalists. Productivity must have been almost entirely dependent on soil fertility and moisture status and may have been marginal compared to present standards. Approximations of crop harvests during the modern period of history are, however, available. Productivity levels of both wet and dry crops were moderate during *Hainu* season and relatively low during *Caru* (Table 1.2). Watt (1889) states that chickpea yield differed according to cultural practices. A rain-fed crop yielded 460 to 750 kg ha^{-1}, Chickpeas grown as sole crop gave 550 to 830 kg ha^{-1}, whereas if mixed with cereals or other legumes, they yielded only 450 to 500 kg ha^{-1}. An irrigated sole crop could produce as much as 1100 kg ha^{-1}. Based on Watt's (1889) document, Nene (2006) suggests that the average productivity of pulses such as black gram (*V. mungo*), green gram (*V. radiata*) and cowpeas (*V.unguiculata*) ranged from 500 to 800 kg ha^{-1} in the agricultural regions of Andhra Pradesh and Tamil Nadu during the 19th century. Pulses were generally confined to fields with low fertility status. Hence, grain productivity was relatively low.

The productivity of pigeonpea in Andhra Pradesh and North Karnataka hovered around 645 kg ha^{-1}. Fields yielding as low as 100 kg pod ha^{-1} were also common (Watt, 1889). During the early to mid 1900s, pigeonpea yield in South India had leveled off at 760 kg ha^{-1} (Nene, 2006). The productivity of rice or any other crop depended on inherent soil fertility status, nutrient balance and organic matter recycling procedures followed by the farmer. During the 1800s, in coastal Tamil Nadu, factors such as inherent soil fertility, agroclimate, water resources, together with farmers' labor resulted in moderate levels of rice harvests. Nutrient dynamics within these cropping zones should have, at best, resulted in rice yield comparable to subsistence farming of the present. Rice productivity during the 1800s was actually moderately low at 510 kg ha^{-1} in Chingleput, 640 kg ha^{-1} in Tinnelvelly and 780 kg ha^{-1} in Madurai (Parthasarathi, 2006). Rice farmers practiced both single and double cropping, depending on local conditions. Double cropping of rice was practiced, if water resources allowed it. To support the greater nutrient demand, farmers intending to raise two crops ploughed 6 to 8 times (or more) and applied large quantities of manure to the first crop. In Tanjavur, manures were prepared using soil from sheep/cattle penning zones, dung, ashes and town sweepings. The second crop, sown usually in October, was sown after a single ploughing and manuring was minimal (Buchanan, 1906). Between the 17^{th} and 19^{th} centuries A.D., dry seeding or broadcasting of rice was common in Mysore, Canara, Coimbatore and Madurai. Parthasarathi (2006) states that transplanting rice became a common mode of raising rice crops only during the early and mid 1900s. The shift to transplanted rice was attributed to better plant density, nutrient recovery from soil and higher grain yield achieved by South Indian farmers. Rice farmers in Malabar practiced transplantation to achieve higher harvests needed by the already increasing population density in Kerala

Let us now consider crop productivity during recent history-1900 till date. The average productivity of major crops grown in India during the first half of 20^{th} century was relatively low, with a clear declining trend in the productivity of some crops. For major crops of South India, the following is the average productivity and decline in crop yields during 1900 to 1947:

	Rice	Jowar	Bajra	Gram	Groundnut
Average yield (kg ha^{-1})	938	495	401	619	890
Percent decline in yield from 1900 to 1947	25	20	16	19	16

Source: Guha, 1992; Naidu, 1941

The productivity of pulse crops during medieval times and up to the 19^{th} century does not seem to vary much with those reported during recent times (Nene, 2006). Some of the reasons quoted include the fact that legumes are generally intercropped, being subordinate to the main cereals grown in the same field. Legumes are usually allocated to soils with low fertility and raised as rain-fed crops. They are not provided with high inputs or regular irrigation.

At present, it is well known that legumes improve soil fertility, especially nitrogen and carbon status. We have no specific information about the presence or absence of inter-cropping prior to the modern period. However, mixed fields are extremely common among pre-industrial agriculturalists the world over. Nene (2006) opines that South Indians obtained the knowledge of benefits to soil fertility due to legume cultivation from West Asians, noting that the soil fertility enhancing property of legumes was mentioned in *Nashua Dar Fanni Fahalat* (Razia Akbar, 2000). However, it seems more likely that farmers, with thousands of years of experience growing leguminous crops in the region, would already have come to that conclusion on their own.

During second half of the 20th century, deterioration in soil fertility especially depletion of soil nutrients was rampant following the introduction of high yielding semi-dwarfs and hybrid rice, hybrid sorghum and finger millet. Initially, during the 1960s, nutrient replenishment schedules were confined to single major nutrient – nitrogen. However, continuous cultivation resulted in deficiencies of other nutrients such as P, K and micronutrients. Eventually, Liebig's law of the minimum took effect in most locations with the nutrient most deficient dictating yield levels. High yielding pulse crops that usually followed cereals also depleted soil nutrients drastically. Since the early 1980s, farmers in South India have begun to replenish their fields with all three major nutrients -N, P, K and micronutrients - based on soil fertility tests. During the past 2-3 decades, a concept called 'Integrated Plant Nutrient Management (IPNM) has been adopted in most parts of South India. This concept envisages the supply of nutrients in balanced proportions through a variety of organic and inorganic sources and also includes the use of microbial inoculants that enhance soil fertility. Incidentally, development and spread of fertilizer technology has played a key role in shaping the evolution of agroecosystems of South India and and their productivity levels. Historically, first fertilizer factory in Southern India got initiated in 1906 at Ranipet in Tamil Nadu. It supplied phosphatic fertilizers. Later, in mid 1900s, combinations of complex fertilizers were developed to provide a balanced nutrition to the crop. Following is the chronology of fertilizer development and usage in South India:

Year	Fertilizer
1906	Single super phosphate
1933	Ammonium sulphate
1939	Ammonium sulphate nitrate
1959	Urea
1959	Ammonium chloride
1960	Ammonium phosphate
1963	Calcium Ammonium Phosphate
1967	Di-ammonium Phosphate
1968	Triple Super Phosphate
1968	NPK complex fertilizers

FAO, 2005

The productivity of major cereals and legumes has improved during the recent period. For example: during the past 4 decades, average rice grain yield improved gradually from 1.2 to 2.7 t ha^{-1} depending on season and irrigation facilities; average sorghum yield has improved from < 500 kg ha^{-1} in the 1950s to 800-1000 kg ha^{-1} in 2005. Similarly, pigeonpea pod yield has improved from 640 kg ha^{-1} in 1960 to 780 kg ha^{-1} and groundnut yield from < 800 kg ha^{-1} in the 1950s to 1200 kg ha^{-1} at present. Annual growth rates have, however, been either stagnant or declining in case of several cereals.

6.4. The Evolution and Development Agroecosystems in South India

Agricultural activity in South India was initiated during the Neolithic, around 3000 B.C. (Korisettar et al., 2001a,b; Fuller, 2005a,b; Misra,2001). Although agriculture developed later in southern India than in northern or central India, Neolithic communities in the south added new crops domesticated *in situ*, to the mix of existing crops and strategies that came to them from the north. Certainly, southern Neolithic people laid the basic foundations of South Indian agriculture, growing a suite of dry crops including grains and legumes. Although new species would be added to this mix through time, this period can certainly be seen as setting the stage for later dry farming strategies of the south. The economy of the Southern Neolithic was agro-pastoral in focus, and permanent settlements shared the landscape with small seasonal camps, ashmounds, and other locations created by their complex, semi-mobile life style. Settlement locations during the Neolithic suggest an interest in harvesting monsoon rainfall, but we have little clear evidence for formal irrigation other than, perhaps, the evidence that water-loving crops may have been grown on a small scale. Hand-watering or pot-irrigation may have supported kitchen gardens where these and other plants were grown.

During the Iron Age and Early Historic, the expansion and intensification of agriculture was guided by several factors. First, regional population densities seem to have increased and, perhaps more critically, very large nucleated settlements first appeared. With growing occupational specialization, it was no longer the case that all or virtually all people generated their own food, so agriculturalists would have had to produce a larger surplus to feed others. Animals, still an important part of subsistence strategies, were used for traction and ploughing may have been practiced. Although arguments have been made that iron tools greatly facilitated field clearing and tillage, especially on the Gangetic plain, we have little direct evidence for this. Perhaps the most important change in this period, one associated with the growing importance of rice and other irrigated crops, was the construction of irrigation facilities, including small canals and reservoirs (Bauer and Morrison, in press). Because there are fewer archaeobotanical studies of sites from these periods as compared to Neolithic sites, it is not clear if the use of temperate cereals such as barley and wheat actually declined, or if they were always grown in limited regions. However, it is certainly the case that rice became a dominant cereal and its cultivation expanded into large portion of South India. Wetland areas supported relatively larger belts of rice and sugarcane, with irrigation playing a major role in this expansion. Because of the extension of irrigation, the productivity of Southern Indian agroecosystems improved, though it is also important to note that dry land cereals and legumes also expanded in area and intensity.

During the medieval period, Southern Indian agroecosystems expanded further into hitherto unexplored areas, in some cases pushing against upland forest zones. Again, human population expansion and concentration induced the rapid expansion of cropping belts during the Vijayanagara era (14 to 17th century). The availability of irrigation, fertile soils, transportation, labor and market demand were other factors that decided cropping patterns in this period. For example, during medieval times, cotton production expanded into the fertile black soils (Vertisols) of North Karnataka and Andhra Pradesh, supported by the expansion of local and international trade in Indian textiles. Although much of this crop was grown under dry land conditions, the availability of riverine irrigation from two of the major rivers of South India - theTungabhadra and the Krishna - may have stimulated production in some areas. Similarly, in the deep South, the fertile alluvial soils of the Cauvery river delta, improved farming techniques, and the administrative zeal of the Cholas and Pandyas facilitated the development of an extensive rice mono-cropping belt. Crop introductions that occurred during medieval period and then became important in the south include groundnut and maize; chilies, potatoes, tomatoes, and other New World crops were also taken into local diets after the 16th century. During the modern period (1700 to 1900), the expansion of agro-ecosystems was easily attributable to improved crop genotypes, implements, more suitable cropping patterns, irrigation facilities and manuring,

During the recent period (1900s), agricultural expansion in South India was rapid. Several major and minor irrigation projects, the advent of chemical fertilizers, improved farming systems, mechanization, high yielding cultivars, economic aid and administrative zeal all together induced an intensification of farming. Agroecological aspects were applicable to larger belts. Monocrops as well as intercropped areas became vast. For example, rice monocrops flourished in Andhra Pradesh and Tamil Nadu. Further, crop genotypes that dominated the ecosystem changed. For example, highly productive semi-dwarf rice genotypes (eg. Jaya, Madhu, PTB) replaced tall, low yielding native cultivars commonly preferred by farmers during the modern era. Nutrient dynamics were affected both at micro and macro levels in these vast mono-cropping expanses. Eventually cropping area, productivity and the total production of South Indian agroecosystems improved enormously. For example, at present, the rice agroecosystem in South India occupies 8.5 m ha and contributes over 24 m t grains annually. Since 1998, the rice agroecosystem' in South India has been experiencing a historically important change in crop genotype. 'Rice Hybrids' that consume relatively high amounts of nutrients (over 230 to 260 kg NPK ha^{-1}) and produce >6-8 t grain ha^{-1} are replacing the semi-dwarfs of the 1970s and 80s rather rapidly. This change will affect the nutrient dynamics of one of the largest agroecosystems in South India. In addition to rice, agroecosystems based on crops such as sorghum, finger millet, pigeonpea, groundnut, sunflower and cotton have expanded enormously during the last century. It is believed that in the future, the expansion of cropping zones for at least certain species such as rice, sugar cane or cotton will be difficult. At present, the total agricultural area in South India is 24.4 m ha. Hence in the future, farmers may intensify these agroecosystems further by adding even greater amounts of nutrients via chemical fertilizers and irrigation. Within limits, the size of specific agroecosystems has fluctuated due to variety of reasons. A few crops never achieved cultivation on a large scale. For example, certain minor millets (*Setaria*), legumes (soybean), oil seeds (e.g. castor, niger, mustard) and many vegetables are confined to smaller zones and occur infrequently. As stated above, during the recent era, the cultivation of a few crops such as wheat or barley is almost extinct in Southern India, with only localized areas of northern Karnataka still producing them on a regular basis.

7. Concluding Remarks

A chronology of historical events related to invention and development of South Indian agriculture, especially those concerning soil fertility and crop production have been delineated in tables 1.4 a and b.

South Indian Agriculture took root during the Neolithic, around 3000 B.C, far later than similar events that occurred in the Fertile Crescent of Western Asia around the beginning of the Holocene or even in northern and central India, where West Asian domesticates were adopted. However, the South Indian Neolithic can boast significant innovation in being built around several crops domesticated *in situ*. Over the centuries, southern farmers showed a continuing willingness to innovate and change, adopting crops with ultimate origins in East Asia, Africa, Europe, and the Americas.

During the Iron Age and Early Historic, several more crops were introduced into the peninsula and patterns of farming shifted with the advent of large towns and socially more complex societies. Farmers adopted diverse cropping patterns to suit the prevailing agroclimates. With the advent of the Iron Age, improvements in agricultural implements were marked. Farming procedures tended to be relatively more efficient. Soil and land management practices such as ploughing, the formation of irrigation channels, inter-culture, and changes in harvesting and processing may have taken place. Most importantly, improvements in irrigation allowed both the expansion and intensification of agricultural crop production.

During the medieval period, agricultural cropping expanded into hitherto unexplored areas in South India. Productivity improved further around the citadels and far-off villages, especially where new irrigation facilities were constructed. The diffusion of crops occurred both ways, both into and outside of South India; some upland crops such as pepper have played an important role in international trade for at least the last two thousand years. Some newly-adopted crops have developed into large expanses, enough to be called agroecosystems (eg. groundnut). The Development of suitable cropping patterns, irrigation facilities, manuring practices and implements played a crucial role in the perpetuation of agroecosystems during medieval times.

Farming became a mainstay for large section of the populace during modern times. Rice, sorghum and millets provided carbohydrates, whereas, pigeonpea cowpea, black gram, green gram and horse gram supplied proteins. Cotton, Oil seed, sugarcane, vegetables and plantation crops also flourished on the peninsula.

Since the mid 1900s, agricultural productivity in South India has improved markedly. Irrigation projects on southern Indian rivers allowed the development of cropping belts large enough to be called agroecosystems. Rice developed into the largest agroecosystem in South India; with the introduction of high yielding semi-dwarfs a major factor in improving grain yield. Similarly, sorghum and cotton have evolved into agroecosystems on Black soils of North Karnataka and Andhra Pradesh. The hill tracts of Kerala and Karnataka support Plantation ecosystems. In general, fertilizer inputs, rapid mechanization, irrigation, better post harvest storage and marketing are some the factors that have resulted in the higher productivity of Southern Indian agroecosystems. During the past five years, 'Rice Hybrids' have been introduced into the South Indian rice belt. Historically, this is an important event. These rice hybrids yield appreciably higher, 20 to 30% above previous levels. However, they also need to be supplied with an excessively high level of fertilizers, beyond 230 -250 kg NPK. Therefore, major alterations in nutrient dynamics and soil quality are to be expected. The gradual adoption of GPS-guided precision farming and computer-supported decision making with regard to fertilizer inputs constitute other changes of historical relevance. Similarly, the spread of transgenic crops such as BT cotton is another important event, with some expecting that the use of pesticides on farms may decrease. Whatever be the period of history, South Indian Agriculture has managed to keep pace with the food demands of the native populace. We may expect it to continue to serve South Indians - and others situated elsewhere -- ably with food, fodder, fiber and cash in the future.

Table 1.4.A. A Chronology of historically important events related to Southern Indian Agriculture: Crop related Events

Year/Age	Crop Related Events
PALEOLITHIC AGE (Before 8-10,000 B.C.)	**Non Agricultural Era**

Early Paleolithic or Acheulian assemblages are traceable on the banks of South Indian rivers such as Krishna, Godavari and Thungabadhra. Several Paleolithic and Mesolithic sites occur in Tamil Nadu. Human beings were nomadic and practiced hunting and gathering way of life. Stone tools like blades, trapezoids, choppers and polyhedrons were used for hunting/butchering (Paddayya 1991; Korisettar et al. 2001a, b; Misra, 2001)

NEOLITHIC AGE	**Agricultural Era Begins**
10-8,000 B.C.	Agriculture invented in Fertilie Crescent and West Asia.
8000 to 6000 B.C.	Wheat, Barley, Oats and Lentils domesticated in West Asia
4500 to 3000 B.C.	Pearl Millet, Sorghum and Cowpea domesticated in West Africa

↓ **Agriculture in South India begins**

3000 B.C.
Beginning of Neolithic Human settlements in South India. Neolithic assemblages are found on the banks of rivers, hill tops, and near lakes in North Karnataka (e.g. Hullur, Sanganakkalu), Andhra Pradesh and Tamil Nadu.

3000 B.C. to 2000 B.C.
South Indian Neolithic settlers domesticated several crops. Following are examples:
Cereals: Brown Top Millet (*Brachiaria ramosa), Bristly Fox tail Millet (Setaria verticellata), Yellow Foxtail Millet (S. pumella), Sawa millet (Echinochloa colona),* Little Millet (*Panicum sumatrense). Kodo Millet (Paspalum scrobiculatum), Pearl Millet (Pennisetum glaucum), Finger Millet, (Eleusine coracana).* Wheat (*Tricitcum durum* and *T. aestivum*), Barley (*Hordeum vulgare*) was introduced into West Asia and North West India.
Legumes: Pigeonpea (*Cajanus cajan*), Mung bean (*Vigna radiata*), Urad (*Vigna mungo)* Horse gram (*Macrotyloma uniflorum*)

2500 B.C.
Cowpea (*Vigna ungiculata*) was introduced from West Africa to South India. Chickpea (khalva) (*Cicer arietinum*) was introduced into peninsula from West Asia (*Brihat samhita*)
Other Crops: Cotton (*Gossypium arborium, G. herbaceum*), Flax (*Linum usitatissimum*) Cucurbits

3000 to 1200 B.C.
Ash mound cultures existed in North Karnataka. Domesticated cattle, sheep goat, swine and Chicken were traceable (Korisettar et al. 2001a, b; Southworth, 2006).

2000 to 1500 B.C. Domesticated rice was introduced into South India from Gangetic Plains

ANCIENT PERIOD (Iron age)
1000 A.D. to 1000 A.D.

1000 B.C. to 500 A.D.
Rice, millets, several types of legumes, oilseeds like safflower, sesamum, mustard and linseed; vegetables like pumpkin, gourds and fruits such as mango and plantains were cultivated by Ancient Southern Indians.

Crop genetic variability was identified. Several types of rice known to differ in size, shape, color and nutritional value were utilized.

Agroclimatic aspects such as precipitation pattern, cloud types, onset of monsoon, crop season, sowing and harvesting schedules were well developed.

200 B.C. to 200 A.D.
Shifting cultivation was practiced in the forest openings. Rice, millets, cotton and certain legumes were cultivated under shifting cultivation system.

700 B.C.
Domesticated field bean-rajmash diffused into peninsula from North.

500 B.C.
Wheat and its culinary aspects was re-introduced into South India from Gangetic Plains, but at a later date, its cultivation was not preferred and it got relegated.

300 B.C.
Rice cultivars moved from Northeast India and Orrisa to Southern India (Randhawa, 1980).

200 B.C.
Peas (*Pisum sativum*) domesticated in Southern Europe moved to South India via West Asia (Nene, 2006).

MEDIEVAL PERIOD
1000 to 1700 A.D.

14th to 17th century
During Vijayanagara period, two main cropping seasons were in vogue, namely '*Mungar*' or rainy season and '*Hingar*' post-rainy season. Several crop species were cultivated. Cereals like rice, sorghum and finger millet were predominant.

Pigeonpea, Cowpea, Black gram and Green gram were main pulses. Oilseeds included sesamum and niger. Several combinations of intercrops and rotations were practiced. Crops such as maize, groundnut and certain vegetables were introduced into South India during Vijayanagara period.

MODERN PERIOD
1700 to 1900 A.D.
Southern Indian farmers, especially those in Karnataka and parts of Tamil Nadu, raised crops at least during two seasons known as *Hainu* (rainy season) and *Caru* (post rainy).

Rice was the major cereal. It was cultivated as transplanted crop (Natti), or direct seed (*Barra butta*) or sprouted seed (*mola butta*) (Buchanan, 1807). Two major sugarcane varieties sown in South India were *Pattapatti*

(Stripped) and *Rustali* (Juicy). Other cereals were sorghum, finger millet and panicum. Several species of legumes, oil seeds and vegetables were also cultivated.

RECENT PERIOD
1900 to PRESENT

1900 to 1950
Crop productivity levels were stagnant. Expansion in cropping belt was marginal. There was also decline in cereal grain harvest during several years.

1960s
Fertilizer usage was encouraged. Semi-dwarf rice spread rapidly into Southern rice belt. Similarly, high yielding short season legumes became common in arable belts.

1970s
Germplasm centers were established for major field and horticultural crops at various Agricultural Institutes. (e.g. Agricultural Universities and Research centers in South India; International Crops research Institute for the Semi-Arid Tropics at Hyderabad; Indian Institute of Horticultural Research at Hessarghatta near Bangalore,

1970-80
A 'Green Revolution' resulted in enhanced crop productivity. It was attributed to increase in chemical fertilizer usage; hybrids and high yielding varieties of various crops; expansion in irrigation and economic aid. Dry land agricultural programs improved crop yield under subsistence farming belts. Animal husbandry programs integrated crops with cattle, swine and poultry in terms of nutrient dynamics, productivity and economics.

2000
'Rice Hybrids' were introduced into South Indian Rice belt.

Table 1.4 B. A chronology of historically important events related to Southern Indian Agriculture:
Soil Fertility, Tillage and Water Resource related events

Year/Age	**Soil Fertility, Tillage and Water Resource related Events**
PALEOLITHIC AGE (Before 10,000-8000 B.C.)	Non Agricultural Era
NEOLITHIC AGE 10-8000 B.C. till 1000 B.C.	**Agricultural Era begins**
10-8000 B.C.	Agriculture invented in Fertilie Crescent and West Asia

8000 to 6000 B.C.
Wheat, barley, lentils other crops grown on Oxisols/Alfisols in West Asia. Mostly, cropping was confined to fertile zones with water resource, swamps, near natural embankments, lakes and ponds.

4500 to 3000 B.C.
Pearl millet, sorghum and cowpea grown on sandy soils in Sub Saharan West Africa. Tillage was minimal or nil on sandy soils of Sub Sahara. These crops tolerate low soil fertility and drought relatively better than others.

↓ **Agriculture in South India begins**

3000 B.C. to 2000 B.C.
Soil fertility concepts were yet rudimentary. However, fertile zones surrounding Southern Neolithic assemblages with water resources for greater duration in a season was preferred. For example, fertile locations nearer to

swamps, ponds, lakes or rivers served as good cropping zones. Tillage was minimal. It was restricted to scratching soils with primitive stone tools and dibbling seeds into pits.

Neolithic settlers practiced cropping on Vertisols (Black soil) in North Karnataka and parts of Andhra Pradesh. Red Alfisols and loamy soils supported farming in Southern Karnataka and Tamil Nadu. Alluvial soils on the banks of rivers like Krishna, Godavari, Thungabadhra and Cauvery were also utilized. Sandy coastal soils too supported cropping surrounding Neolithic settlements in Tamil Nadu and Andhra Pradesh. There is no evidence for use of plough or a similar large implement to mend soils during early Neolithic phase. However, some kind of soil tillage occurred through the use of small stone implements like axes, adzes, sharp blades and wedges. It allowed Neolithic settlers to loosen soil and dibble seeds into small pits (Fuller, 2005a.b; Southworth, 2006)

ANCIENT PERIOD
1000 B.C to 1000 A.D.

1000 B.C.
Southern Indians, it seems, used ploughs, for the first time during Rig Vedic era. Ox-drawn large ploughs with shares were regularly used to attain good soil tilth. Heavy plough called *Sira* provided deep tilth. Ancient South Indians used harrows and hoes. These implements helped them in preparing soils for sowing, smoothening, loosening and inter-culture.

200 B.C.
During Iron Age, Ox-drawn ploughs with iron shares were regularly utilized. Several implements such as furrow makers, iron axes, adzes and shovels were used to accomplish farm operations

200 B.C. to 200 A.D.
Rivers, canals (*kulya*), tanks with sluice gates to regulate water flow, lakes ponds, ground water (*khanathrima*) and wells (*kupa*) were used in ancient South India to muster water for crops. *Yetam* was used to lift water from wells. Megalithic South Indians in Tamil Nadu used water from rivers like Cauvery, Vegavathi and Palar to support their cropping zones (Sangam literature).

Soil fertility aspects were considered while deciding type of crop sown. Fertile soils with potential irrigation were allocated to rice and sugarcane. Drier tracts with sandy soils low in fertility were used for raising hardy legumes like horse gram. Manures were prepared using farm residues, crop wastes, cow dung etc. Farmyard manure was applied to sustain soil fertility. Agricultural fields were generally classified based on soil fertility status and irrigation sources.

MEDIEVAL PERIOD
1000 A.D. to 1700 A.D.

1350s to 1600 A.D
During Vijayanagara period agricultural fields were classified based on water resources used on them and irrigation potential. Wetlands *(Gadde)* supported rice cultivation. Irrigated areas (*Niravari pradesha*) and Dry lands (*Marubhoomi*) were used to raise arable crops. Soil fertility concepts were well recognized. Manures were derived from farm animals, crop residues and vegetation. Manuring soils prior to seeding was a regular procedure. Fields were fallowed periodically to refurbish the *sara* (fertility) of soils. Soil erosion control measures such as mulching and contour bunding was in vogue. Rivers, tanks, lakes, ponds, well and other ground water sources were harnessed to irrigate crops. Small dams and sluices (*tubu* or *madai)* to regulate water flow were common in dry belts.

MODERN PERIOD
1700 A.D. to 1900 A.D.

Major soil types utilized for farming in South India were Black soils (*Erray, Krishna* or *Mucutu*), Red soils (*Kempu bhoomi*) and Sandy soils (*Maralu*).

Wetlands meant for rice and sugarcane as well as dry lands for all other arable crops was clearly demarcated around the villages/settlements. In Kerala, low lands (*Ubhayum*) were utilized for paddy cultivation and uplands (*Pallielil*) for arable crops.

Fields were ploughed using wooden ploughs with iron shares. Marked with furrow makers and sown by hand or Ox drawn planters. Ox drawn ploughs were common in Karnataka and Tamil Nadu. Ploughs (*negilu, sira*), harrows (*halivay*) and hoes (*cuntay*) of different sizes to suit the purpose were available. Weeding was accomplished using *Ujire* or *Varvari*.

Crops were irrigated using rivers, tanks, lakes or pond water. Soil fertility was refurbished by manuring with farmyard manure.

RECENT PERIOD
1900-TILL DATE

1940S- 80s
South Indian farmers were exposed to use of chemical fertilizers to improve soil fertility. Several fertilizer industries were commissioned to provide fertilizers to farming community.

1950s-1990s
Large-scale soil survey and land use programs were initiated covering all riverine, fertile cropping belts and dry land areas. In South India, regular use of fertilizers on High yielding varieties improved productivity.

1970s-80s
Irrigation potential in Southern Indian farming belts was vastly improved. Dams were built on almost all Southern Indian rivers. Several major and minor irrigation projects were initiated.

1960s -1980s
Mechanization was rapid. Tractors, power tillers and several other farm equipments were introduced. Percapita use of tractors increased enormously. Farm electrification and use of pump sets improved irrigation potential further.

1980s -1990s
Advanced methods of Soil and Crop management were employed. For example, soil nutrient analysis, Integrated Plant Nutrient Systems (IPNS), GPS-based Precision Farming or Site Specific Nutrient Management, Sprinklers and Drip system, sprayers, mechanical harvesters and processors were regularly utilized.

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