AGROECOSYSTEMS

OF

SOUTH INDIA

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Nutrient Dynamics, Ecology and Productivity

K.R.KRISHNA

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Global Agricultural Fraternity

PREFACE

Historically, seeds for Agroecosystems of South India were sown around human settlements during early phase of Neolithic period (3rd millennium B.C.). Human ingenuity and migratory trends played a key role in domestication and dissemination of crop species. It induced counter currents of crop diffusion into and out of South Indian peninsula. Several crop species were domesticated *in situ*; many others like sorghum or cowpea reached South Indian shores via seafarers and merchants from African Continent. Rice diffused into South India from Eastern Gangetic plains around 1500 B.C. Legumes like chickpea and peas were derived from West Asia and Northwest Indian plains. First bout of accentuation or intensification of cropping and a semblance of agroecosystems seem to have taken shape around ancient period (Iron age). During medieval period cropping expanses were larger around citadels and riverine zones. A definite improvement in cropping pattern and larger sized agroecosystems came into existence in 19th century. During very recent period, beginning in 1950s, drastic alterations occurred in Agroecosystems of South India, especially with regard to crop genetic stocks, cropping pattern, soil fertility, nutrient management procedures and irrigation. At present, South Indian agroecosystems sprawl into 18.5 m ha. Together, they contribute 25.5 m t grains and nourish over 233 m people plus supply fodder to cattle.

Within the context of this book on 'Agroecosystems of South India', an agroecosystem has been defined as a conglomerate of small cropping areas, may be monocropping expanses or intercrops that occur in different states or geographic regions within South India. South India abounds with several such Agroecosystems that encompass field crops, vegetables, cash crops, plantations and forest species. However, main emphasis within this volume is restricted to Agroecosystems that include major cereals like rice, sorghum, maize and finger millet; legumes like pigeonpea, black gram, green gram, cowpea, horse gram and chickpea; and two major oil seed crops – groundnut and sunflower. A few crop species like Pearl millet, Setaria, Panicum, Lablab beans and Castor have not been included, although they are cultivated in small patches around several locations within South India.

There are 10 chapters in this volume. The first one on Historical aspects of South Indian Agriculture traces important events related to initiation, development and perpetuation of agroecosystems. Discussions are focused on historical facts related to domestication, introduction of crop species, agricultural implements, development of soil fertility and crop husbandry procedures.

An introductory chapter on Agroecosystems delineates the various Agroecoregions of South India. Their classification based on physiography, soils and climatic parameters have been provided in great detail. Agroecosystems thrive mainly on natural resources or ingredients like crops, their species and genotypes; soil types and their fertility status, precipitation pattern and other water resources; as well as climatic conditions that prevail in a region. Detailed descriptions on natural resources that influence agricultural cropping in South India, namely Soil types, Crop species and their Genetic stocks, Fertilizers and Water resources are available in chapter 2.

Agroecosystems of South India have kept pace with human demand for staple food. These agroecosystems have supplied sumptuous quantities of food grains and fodder despite periodic onslaughts of drought, disease and fluctuations in soil fertility. They have supported an assortment of crops. Cereals such as rice, sorghum, maize and finger millet; a few legumes like pigeonpea, black gram, green gram and horse gram; plus oil seeds like groundnut and sunflower dominate South Indian agricultural expanses. Rice belt constitutes largest of agroecosystems in South India. It occupies 8.5 m ha and contributes 24 m t grain annually. It also garners 48 % of fertilizers and 52 % of irrigation facilities available to South Indian farming community.

The impact of soil fertility and nutrient dynamics on productivity of crops in an agroecosystem forms the central piece of discussion within chapters 3 to 9. Introductory topics such as Historical background, geographical settings, agroclimate, soils, cropping systems and productivity trends have been provided for each of the cropping ecosystem. Recent advances and details on aspects of Nutrient Dynamics, such as Soil nutrients, their availability, Physico-chemical transformations, Nutrient fluxes, Inorganic Fertilizer supply, Organic manures, Crop residue recycling, Nutrient accumulation trends, nutrient carry over and nutrient balances/imbalances form the core of each chapter. Role of beneficial Soil microbes such as Rhizobium and Arbuscular Mycorrhizas on nutrient dynamics in soil have been discussed. More recent developments dealing with modeling nutrients in cropping ecosystems, computer based-simulations, Precision farming and Site-Specific Nutrient Management have been emphasized.

The future of South Indian Agroecosystems perhaps deserves greater attention from Policy makers and Researchers. These Agroecosystems are dynamic. They may encounter drastic changes in order to nourish and satisfy dietary preferences of a slightly enlarged population. Plus, farmers consistently desire to enhance land-use efficiency and productivity. Therefore, general trend is to intensify Agroecosystems, using high yielding genetic stocks and by supplying larger amounts of manure and irrigation. Forecasts on effect of nutrient supply on crop productivity trends and ecosystematic functions need due attention. *Systematic Intensification and De-intensification* of individual fields, small patches or large expanses of crops seems pertinent. Such initiatives may allow us to regulate nutrient dynamics, thwart green house effects if any, and still provide higher grain/fodder productivity.

Over all, this book is a scholarly edition on 'Agroecosystems of South India'. It aims at providing an excellent exposition of various Agroecosystems of South India and their current status to global audience. It highlights importance of Soil Fertility and Nutrient Dynamics within Agroecosystems to total food grain and fodder production in South India. It will be a useful book to Researchers, Professors and Students dealing with Agriculture, Environmental Sciences, Ecology, and Plant Science.

Bangalore   Dr. Kowligi Krishna PhD Agric.

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I wish to thank my wife Dr Uma Krishna and son Sharath Kowligi

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CONTENTS

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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 (5^{th} or 4^{th} 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 4^{th} 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 cylindrica*l); 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 (L*athyrus 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