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INTEGRATED FARMING SYSTEM FOR SUSTAINABLE AGRICULTURE: A REVIEW

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ABSTRACT

The corresponding fall in per capita availability of land almost dictates the development calls for provisionally management and envisages a vista of opportunities meted with propitious agri-technologies to offer adequate employment alongside income generation so that large scale poverty stricken section, especially small-holders (those farmers who cultivate predominantly less than 2.0 ha), could persuade at least some windows open into sunshine leading towards better economic empowerment besides food security safeguard pivots all across developing world. A single farm enterprise- eg mono-cropping system, probably will never enable the small-holder-farmer to subsist. Integrated farming systems (IFS) have the potential to be less risky when well-managed, due to more synergy among enterprises leading also to higher product diversity and environmental cleaner production. Hence IFS have been advocated as a means to promote marginal and small farms in Asia July but researchers like de Schutter developed several strategies, which helped the risk free and continuation of farming systems offered supplementary income, employment on land holders-based farmers. But these IFS never attained saturation and popularity. The present review aims to address this scarcity by providing view on various concepts and advantages of IFS which farmers can avail.

Keywords: Farming system, enterprise, crops, dairy, poultry, fishery, agroforestry, mushroom, apiary, sericulture, biogas, interactions, r small farmers, integrated farming.

Introduction

Several authors have suggested the use of farming systems approach in research and development settings to address these challenges comprehensively, such as those associated with poverty alleviation or food security, improving competitiveness while maintaining sustainable production. A farming system is an outcome of complex interactions between a set of inter-dependent elements with which it consists and, in some cases, artificially design and executed by the collective/farmer for land, labor capital, management available to them (Mahapatra 1994). Introduction Farmers Systems Research (FSR) has been known as an important tool in the management of natural and human resources under farming. Farming system is a unique concept which was generically developed keeping its application specifically to developing countries like India. This is considered as an Integrated, Holistic Farming Strategy that works well-enough to address the woes of small and marginal famers. This approach is primarily geared to enhance income and employment options drawn from smallholdings through integration of diverse farm enterprises and recycling of agricultural residues, wastes within the own land ecosystem (Behera & Mahapatra, 1999; Singh *et al.*, 2006; Bhargavi & Behera).

In a country that is predominantly agricultural, and through the continued reduction in landholding sizes due to family divisions there is an enormous difficulty improving sustainability and profitability. With the significant reduction in per capita land availability from 0.5 hectares at the time of independence to just about 0.15 hectares by the end of twentieth century, and projected shrinkage to less than 0.09 hectare per person by 2030 (GOI, MOA), there is an urgent need for evolving strategies and agricultural technology packages that help farmers securing sufficient employment as well income opportunities especially small & marginal walks who constitute over-85 % of farming population. The intent of research targeting crops and cropping systems should evolve to an entire farming system-based perspective, and be conducted in a holistic manner so that resource management by the farmers can become as efficient as possible (Jha, 2003). With the decreasing size of land holding taking place in an increasing rate, it is important to mix various enterprises like aquaculture poultry and duck farming, bee-keeping as well as field/horticultural crops which are site specific to farmers' biophysical & socio-economic milieu so that there can be multiplier effects into farmer's pocket against his /her investment incurred towards supporting each other leading profitably augmenting apparently unreliable farm activities (Behera *et al.,* 2004). Without integrated farming systems, it is doubtful that any single farm enterprise can provide livelihood support to small and marginal farmers in the long term that ensure adequate income generation and meaningful employment throughout the year (Mahapatra, 1992; 1994). Consequently, the farming systems approach represents a significant framework for tackling the challenges associated with sustainable economic development among farming communities in India.

The principal objective of IFS is to establish a set of practices pertaining to resource development and utilization that culminate in a significant and sustained enhancement of agricultural output (Kumar and Jain, 2005). Integrated farming systems are frequently characterized by lower risk profiles; when managed effectively, they benefit from synergistic interactions among enterprises, product diversity, and environmental sustainability (Lightfoot, 1990). On this foundation, various scholars have proposed IFS models aimed at the advancement of small and marginal farms throughout the nation (Rangaswamy *et al.,* 1996; Behera and Mahapatra, 1999; Singh *et al.,* 2006).

Definition of farming systems

Farming System constitutes a multifaceted interrelated construct comprising soil, flora, fauna, agricultural implements, power, labor, capital, and various additional inputs, which are partially governed by farming households and are shaped to differing extents by political, economic, institutional, and social forces operating at multiple levels" (Mahapatra, 1992). The designation "farming system" pertains to a specific configuration of agricultural enterprises that are managed in response to the physical, biological, and socio-economic environment and aligned with the objectives, preferences, and resources of the farmer (Shaner *et al.,* 1982). "The household, as well as its resources and the resource flows and interactions at the individual farm levels, collectively constitute what is referred to as a farm system" (FAO, 2001).

"Systems" can be characterized as an organized, unitary entity composed of two or more interdependent and interacting components, parts, or subsystems that are delineated by an identifiable boundary or its overarching environmental super system (Behera and France, 2022). This concept represents a collection of interrelated elements, each of which is associated, whether directly or indirectly, with other elements, ensuring that no subset is under-related to any other subsets. Within a systems approach, the entirety of the farm, rather than individual crops or enterprises, is considered prior to any decision-making related to the selection of enterprises and/or technological interventions.

The farming systems can be elucidated and comprehended through an examination of their structure and functionality. The structure, in its broader interpretation, encompasses, among other factors, land use patterns, production relations, land tenure systems, the size of holdings and their distribution, irrigation practices, marketing mechanisms including transport and storage, credit institutions, financial markets, as well as research and educational frameworks. Consequently, the "farming system" emerges as the product of intricate interactions among numerous interdependent components. In pursuit of this system, the individual farmer allocates specific quantities and qualities of the four factors of production: land, labor, capital, and management, which access processes such as crop production, livestock management, and off-farm enterprises in a manner that, within the bounds of their knowledge, aims to maximize the realization of the goals they endeavor to achieve.

The Farming System, as a conceptual framework, encompasses the components of soil, water, crops, livestock, labor, capital, energy, and other resources, with the farm family positioned at the center, managing agricultural and associated activities. The farm family operates within the constraints of its capabilities and resources, the socio-cultural context, and the interactions of these components with physical, biological, and economic factors.

Farming system emphasizes

The interdependencies among components under the stewardship of the household and, The manner in which these components interact with the physical, biological, and socio-economic factors, which lie beyond the control of the household. The farm household is regarded as the fundamental unit of the farming system, encompassing interdependent farming enterprises conducted on the farm. Farmers face a multitude of socio-economic, bio-physical, institutional, administrative, and technological constraints. The operator of the farming system is the farmer or the farming family.

Core Characteristics

Numerous fundamental activities associated with FSR/E can be implemented through various methodologies. The framework is receptive to a myriad of interpretations. Despite the discrepancies in the understanding of FSR/E among practitioners, the approach possesses specific salient characteristics. These include:

i) **It is problem solving:** As a pragmatic approach to problem resolution, it underscores the importance of cultivating and disseminating suitable technologies to mitigate production limitations by diagnosing biophysical, socio-economic, and institutional impediments that affect technological interventions.

ii) **It is holistic:** The entire agricultural enterprise is conceptualized as an integrated system comprised of interrelated sub-systems, with no individual enterprise evaluated in isolation from the broader context.

iii) **It acknowledges the location specificity of technological solutions:** By recognizing the unique characteristics of agricultural production challenges tied to specific locales, it accentuates the necessity of testing and adapting technological solutions in accordance with agroecological and socio-economic particularities.

iv) **It defines specific client groups:** There is a pronounced focus on the identification of distinct and relatively homogeneous groups of farmers facing analogous issues and circumstances, for whom technology is to be developed as targeted client groups. Based on shared environmental criteria, production methodologies, and management practices, it is essential to delineate relatively homogeneous recommendation domains.

v) **It is farmer participatory:** The fundamental tenet is that effective agricultural research and development initiatives should commence and conclude with the involvement of farmers (Rhoades and Booth, 1982). Farmer engagement is facilitated at various phases of the technology generation and dissemination processes, including system characterization, problem identification, design and execution of on-farm trials, and the provision of feedback through systematic monitoring and evaluation.

vi) **The Indigenous Technical Knowledge (ITK) system is accorded significant importance:** The Indigenous Technical Knowledge, which has been rigorously validated at the level of farmers for sustainability through a dynamic process of assimilating new innovations as they emerge, necessitates comprehensive comprehension by scientists and its appropriate application in their research endeavors.

vii) **It pertains to a 'Bottom-up' research methodology:** This approach initiates with a thorough understanding of the prevailing farming system and the identification of principal production constraints.

viii) **It embodies an interdisciplinary approach:** This framework places a heightened emphasis on collaborative engagement among scientists from diverse fields of specialization to address agricultural challenges pertinent to farmers.

ix) **It underscores extensive on-farm undertakings:** It encompasses problem analysis via diagnostic surveys, on-farm evaluation of developed technologies, and the provision of feedback through assessment to shape the research agenda of experimental stations. Furthermore, it offers a structural framework for farmers to articulate their preferences and utilize their evaluative criteria for the selection of technologies that align with their specific circumstances.

x) **It is attuned to gender considerations:** By explicitly recognizing the gender-differentiated roles within farm families in agricultural practices, it underscores the necessity for a critical examination of farming systems through the lenses of activity analysis, resource access and control, benefit allocation, and the implications for formulating pertinent research agendas.

xi) **It adopts an iterative process:** Rather than seeking comprehensive knowledge of a system all at once, it necessitates a systematic analysis of only the most critical functional relationships

xii) **It is characterized by dynamism:** This framework entails ongoing analysis of farming systems, facilitating continuous learning and adaptation.

xiii) **It acknowledges interdependencies among various stakeholders:** The generation, dissemination, and adoption of relevant technologies aimed at enhancing agricultural productivity and sustainability necessitate productive and interactive linkages among policy planners, scientists, developmental organizations, and farmers. This approach places considerable emphasis on this crucial aspect.

xiv) **It prioritizes actual adoption:** The effectiveness of this framework is to be evaluated based on its influence on the production of socially beneficial technologies that rapidly disseminate among designated groups of farmer clients.

xv) **It is oriented towards sustainability:** This framework aims to leverage the strengths inherent in existing farming practices while ensuring that productivity advancements are ecologically sound. In pursuit of preserving the natural resource base and fortifying the agricultural production foundation, it endeavors to develop technologies that are environmentally sustainable and economically viable.

xvi) **It serves to complement research conducted at experimental stations:** This approach not only complements but does not replace research undertaken at experimental stations. It must draw upon the scientific knowledge and technologies cultivated at such research facilities. It is essential to recognize that this approach is not being promoted as a universal solution to all challenges faced by local agricultural production systems.

Integrated Farming Systems (IFS)

An Integrated Farming System (IFS) may be characterized as the amalgamation of two or more typically distinct components or enterprises, which subsequently function as subsystems within a comprehensive agricultural framework. The two principal attributes of an IFS include: (i) the utilization of waste or by-products, wherein the residuals or by-products generated by one subsystem serve as inputs for a subsequent subsystem; and (ii) enhanced spatial utilization, whereby the two subsystems effectively occupy a portion or the entirety of the spatial requirements designated for an individual subsystem. Integrated farming is further delineated as a biologically oriented IFS which: (i) amalgamates natural resources and regulatory mechanisms into agricultural practices to maximize the substitution of external inputs; (ii) ensures the sustainable production of high-quality food and ancillary products through ecologically advantageous technologies; (iii) fosters the sustainability of farm income; (iv) mitigates or diminishes the sources of contemporary environmental pollution attributable to agricultural activities; and (v) promotes the multifaceted functions of agriculture (IOBC, 1983).

Consequently, an IFS embodies a diverse array of crops (e.g., cereals, legumes, tree crops, vegetables) and multiple enterprises (e.g., livestock, apiary, aquaculture) within a singular farm context in a synergistic manner (Behera *et al.,* 2015a). The IFS paradigm adopts a holistic, multidisciplinary, problem-solving, location-specific, and farmer-centric approach (Singh *et al.,* 1998). The fundamental objective of IFS is to establish a compendium of resource development and utilization methodologies that culminate in a significant and sustained augmentation of agricultural productivity (Kumar and Jain, 2005). Nevertheless, a complex web of interactions exists among the components within agricultural systems, rendering the management of such interconnected systems challenging. This complexity likely accounts for the sluggish and limited advancements witnessed in the domain of farming systems research across Asian nations.

For the smallholder and marginal farmers in India, IFS has the potential to substantially enhance their economic conditions and livelihoods (Devendra and Thomas, 2002a, b; Singh *et al.,* 2006). In contrast to specialized farming systems, IFS activities concentrate on selected, interdependent, interrelated, and frequently interconnected production systems that encompass several crops, animals, and associated subsidiary professions. An IFS entails the employment of primary and secondary outputs from one system as fundamental inputs for other systems, thereby rendering them mutually integrated into a cohesive unit. There exists a necessity for effective linkages and complementarities among diverse components to cultivate efficient holistic farming systems (Singh *et al.,* 2007).

When one conducts a comparative analysis of a specialized agricultural system vis-à-vis an integrated farming system (IFS), numerous distinctions arise concerning their structural, functional, and managerial attributes. In advanced nations (e.g., the United States, the United Kingdom, Germany, Australia), the agricultural framework is predominantly defined as specialized farming. This particular agricultural modality is characterized by significant levels of mechanization coupled with extensive reliance on external inputs, wherein approximately 1% of the population engages in the cultivation of extensive land holdings (Behera *et al.,* 2013). Consequently, production expenditures remain relatively low, and the agricultural enterprise is regarded as a commercial endeavor by the farmer. A noteworthy characteristic of this agricultural paradigm is that the farmer who cultivates the commodities on his property seldom partakes in the consumption of his own outputs; rather, he opts to procure such products from retail outlets for personal use. Conversely, in numerous developing nations (e.g., India, Bangladesh, Nepal, Pakistan), agricultural practices are predominantly defined as multi-enterprise integrated or mixed farming systems. In India, where 60% of the populace is reliant on agriculture, subsistence farming prevails, leading to a primary inclination for farm families to utilize the majority of their agricultural yield for personal consumption. As a result, the IFS has emerged as a focal point for the Indian government's developmental initiatives, particularly emphasizing support for small and marginal farmers to enhance livelihood security and to instigate a second Green Revolution within the nation (Matapatra and Behera, 2011; Behera *et al.,* 2013). In this framework, systematic research initiatives are currently underway in India aimed at the formulation of sustainable IFS models tailored for small and marginal farmers, alongside the implementation of various international and national projects.

Concept of an ideal IFS

A viable Integrated Farming System (IFS) should present minimal risk to agricultural practitioners, necessitate minimal capital investment, yield rapid financial returns, and be characterized by simplicity and replicability (Prein, 2002). An exemplary IFS would fulfill five fundamental criteria: (i) economic viability; (ii) nutritional adequacy; (iii) ecological sustainability; (iv) energy independence; and (v) adaptability to climatic variations. It should be capable of generating adequate income and employment prospects to sustain the livelihoods of the farmer and their family (Behera *et al.,* 2015a). Additionally, it ought to facilitate a nutritionally balanced diet through the diverse array of farm products, fulfilling the dietary requirements of the entire household. Moreover, it should promote sustainability by minimizing waste through the efficient utilization of by-products and the effective recycling of waste within the IFS framework. Such practices would contribute to the mitigation of greenhouse gas (GHG) emissions as well as the contamination of groundwater resources (e.g., resulting from nitrogen leaching due to fertilizer application). Furthermore, the integration of a variety of enterprises can help preserve biodiversity, which is crucial for delivering ecosystem services and upholding a high standard of ecosystem integrity (Tuomisto *et al.,* 2012). Ecosystem services encompass the range of ecosystem functions that are beneficial to human beings (Kremen, 2005), many of which are essential for human survival (e.g., climate regulation, air purification, crop pollination), while others serve to enhance the quality of life (e.g., aesthetic value). An ideal IFS would minimize or entirely eliminate reliance on fossil fuel energy and even generate an energy surplus that can be marketed, thereby constituting an additional product from the agricultural operation. Nonetheless, such an energy surplus must be realized without encroaching on the land and resources designated for food crop production. Ultimately, the intrinsic characteristics of farming within an ideal IFS, marked by its diverse range of enterprises, can function as a mechanism for risk mitigation in response to climatic fluctuations that may potentially result in crop failures. The integration of contemporary energy solutions within an IFS could yield a superior agricultural system, provided that the aforementioned constraints are adequately addressed.

The objectives and benefits of an integrated farming system

The overarching aim is to develop technically feasible and economically sustainable agricultural systems through the integration of cropping practices with allied complementary enterprises across irrigated, rain-fed, coastal, arid, and mountainous regions, with the intention of facilitating income generation and employment opportunities within the agricultural sector.

The specific aims include: (i) to identify and evaluate the viability of existing farming systems within designated areas; (ii) to design comprehensive farming system models that incorporate primary and allied enterprises tailored to diverse agricultural contexts; (iii) to promote the optimal utilization and conservation of available resources while ensuring the effective recycling of farm residues and by-products within the agricultural framework; (iv) to sustain a productive agricultural system without compromising the integrity of the resource base and the environment; and (v) to enhance the overall profitability of family farms by fostering synergies between primary and allied enterprises.

The benefits of integrated farming systems (IFS) encompass: (i) the pooling and sharing of resources and inputs; (ii) the efficient utilization of family labor;

(iii) environmental conservation; (iv) the preservation and effective utilization of farm biomass, including non-conventional feed and fodder resources; (v) the productive use of manure and animal waste; (vi) the regulation and enhancement of soil fertility and health; (vii) the generation of income and employment opportunities for a significant number of individuals; and (viii) the augmentation of economic resources.

I. **Productivity:** Integrated Farming Systems (IFS) present a significant opportunity to enhance economic output per unit area and time through the intensification of crop production and associated enterprises (Manjunath and Itnal 2003a; Ravisankar *et al.,* 2007; Rathore and Bhatt, 2008).

II. **Profitability:** The profitability of agricultural ventures is augmented by the reduction of production expenses via the recycling of wastes and by-products generated from one enterprise, which are repurposed as inputs for other enterprises (Maheswarappa *et al.,* 1998; Manjunath and Itnal, 2003b; Ravisankar *et al.,* 2010).

III. **Sustainability:** The practice of organic supplementation through the effective utilization of by-products from interconnected components fosters the sustainability of the production base over extended durations. This approach underscores the importance of attaining agro-ecological balance by mitigating the accumulation of pests and diseases (Korkanthimath and Manjunath, 2009; Gill *et al.,* 2010; Kumar *et al.,* 2011).

IV. **Balanced food:** Diverse components are interlinked to yield various products and agricultural produce, thereby facilitating the provision of a nutritionally balanced diet for the farming household (Kumar *et al.,* 2011, 2012, 2013).

V. **Environmental safety:** Within an Integrated Farming System (IFS), waste materials are adeptly recycled through the interconnection of suitable enterprises and components, thereby reducing environmental pollution. It is acknowledged that farming methodologies reliant on a singular enterprise pose threats to ecological integrity. For instance, the incineration of rice residues is a prevalent practice in regions characterized by intensive rice-wheat cropping in India (e.g., Punjab, Haryana, Western Uttar Pradesh), leading to substantial nutrient depletion and an exacerbation of greenhouse gas emissions in the atmosphere (Kumar *et al.,* 2013). Such detrimental scenarios can be mitigated through agricultural diversification, incorporating additional enterprises (e.g., animal husbandry) into the farm structure. Rice straw can be utilized as livestock feed and subsequently converted into manure to promote soil health. Furthermore, as an IFS prioritizes the efficient utilization of resources and nutrient recycling, it reduces reliance on external inputs, consequently minimizing environmental pollution associated with the excessive use of such inputs (Shukla *et al.,* 2002).

VI. **Resource recycling:** The efficient recycling of waste materials and by-products, such as crop residues and livestock excreta, is effectively implemented within an Integrated Farming System (IFS). Consequently, there is a diminished dependence on external inputs, including fertilizers, agrochemicals, feeds, and energy sources. This paradigm fosters a more resilient and stable production system (Kumar *et al.,* 2013).

VII. **Income year round:** Integrated Farming Systems (IFS) facilitate a consistent financial stream for farmers throughout the calendar year through the commercialization of a diverse array of agricultural products, encompassing milk, eggs, mushrooms, vegetables, fruits, and grains (Behera and Mahapatra, 1999; Maheswarappa *et al.,* 2001; Kumar *et al.,* 2013).

VIII. **Risk minimization:** The provision of a stable and sustainable production framework by an Integrated Farming System, characterized by diversification in both crops and enterprises, contributes significantly to risk reduction and enhances resilience against climate change (Ayyappan and Arunachalam, 2014). Agriculture reliant on a singular commodity is perpetually vulnerable to natural calamities, such as floods, droughts, and disease outbreaks. For instance, during the period of 1999-2000 in India, numerous cotton cultivators in the states of Andhra Pradesh, Maharashtra, and Karnataka resorted to suicide due to severe pest-induced crop damage. The implementation of an Integrated Farming System could assist farmers in circumventing such predicaments and mitigating the risks associated with crop failure (Shukla *et al.,* 2002). Given that an IFS encompasses multiple enterprises, including livestock, aquaculture, and poultry, alongside crop production, it furnishes farmers with a spectrum of opportunities to diminish risk. Approximately 63% of the total cropped area in India, characterized by mono-cropping practices, relies on rain-fed irrigation. These regions are particularly susceptible to crop failures induced by drought and other erratic climatic conditions. The diversification of agricultural practices, incorporating intercropping, agroforestry, horticulture, livestock, and plantation crops, would serve to minimize risk while simultaneously enhancing farmers' incomes in such areas.

IX. **IFS for enhancing sustainable agriculture:** The prevalence of monoculture and continuous cropping systems, such as rice-wheat and rice-rice, has engendered numerous disadvantages, including the degradation of natural resources, the proliferation of diseases and pests, and a decline in productivity factors (Ayyappan and Arunachalam, 2014; Singh 2015). These adverse effects have jeopardized the foundational principles of sustainability within some of India's most agriculturally productive regions. Crop-animal systems prevalent in Asian agriculture exhibit considerable diversity in cropping methodologies, livestock varieties, and resource utilization. Evidence suggests that the interactions between crop and animal systems yield positive economic benefits that promote sustainable agricultural practices and enhance environmental conservation (Devendra, 2002a). The pressures of intensive agricultural practices have precipitated environmental degradation in numerous economically advanced nations, largely attributed to the excessive application of high-energy inputs such as fertilizers and pesticides. The utilization and recycling of locally sourced inputs, combined with the judicious application of minimal external inputs, would bolster the sustainability of agricultural practices. Additionally, the employment of locally available resources, while being ecologically benign, can ensure that production costs remain within a manageable threshold for subsistence farmers. Indigenous technological knowledge plays a pivotal role in facilitating this process. Integrated Farming Systems are advantageous due to their capacity for increased diversification, intensification, enhanced efficiency of natural resources, elevated productivity, and improved sustainability (Lightfoot *et al.,* 1993; Devendra, 1997; Dalsgaard and Prein, 1999).

Components of IFS

The prospective enterprises that hold significant relevance in the agricultural system, particularly in their capacity to exert a substantial influence on farming by facilitating adequate income generation, employment opportunities, and ensuring livelihood security, are delineated as follows:

Crop Production: Crop production constitutes a fundamental agricultural practice that is universally adopted by farmers. It represents an essential component of agricultural operations within the nation. Cropping systems that are designed in accordance with climatic conditions, soil characteristics, and water availability must be developed to achieve optimal production levels through the efficient utilization of available resources. The cropping system ought to ensure sufficient food supply for the household, adequate fodder for livestock, and the generation of ample cash income to cover both domestic and cultivation expenditures. These goals can be effectively accomplished through the implementation of intensive cropping methodologies. Techniques of intensive cropping encompass multiple cropping and intercropping strategies. However, intensive cropping may present certain practical challenges, such as reduced turnaround time for land preparation prior to planting the subsequent crop and labor shortages during peak agricultural activity periods. Such practical impediments can be effectively mitigated through adjustments in cropping methodologies. Modifications in crop geometry may facilitate the incorporation of intercrops without compromising the population of the primary crop.

Sequential Cropping Systems: In sequential cropping systems, the preceding crop exerts a significant influence on the subsequent crop. This phenomenon includes complementary effects, such as the nitrogen released from the residues of the prior crop, particularly legumes, benefiting the following crops, as well as the residual effects of fertilizers applied to earlier crops. Conversely, adverse effects may arise, including allelopathy, temporary immobilization of nitrogen attributable to the extensive carbon-to-nitrogen ratio of the residues, and the carryover effects of pests and diseases.

In India, food crops are predominantly cultivated during the most favorable seasons, rendering specific food crops fundamental to the cropping systems adopted by farmers. Consequently, these cropping systems are typically categorized as follows:

Rice-based cropping system Sorghum-based cropping system Pearl millet-based cropping system Wheat and gram-based cropping system

Additionally, certain cropping systems centered on commercial crops include (i) cotton-based, (ii) groundnut-based, (iii) sugarcane-based, (iv) plantation crop-based, and (v) vegetable-based cropping systems.

The potential for grain production across various regions of the country under intensive cropping practices ranges from 11 to 18 tons per hectare. In the maize-potato or toria-wheat-moong system implemented at the Indian Agricultural Research Institute (IARI) in New Delhi, it has been feasible to yield 14 to 15 tons of food per hectare annually without compromising soil health. Demonstrations of multiple cropping under irrigated conditions illustrated that production potential could reach as high as 19.8 tons per hectare within a cereal-based cropping system of rice-rice-rice. The yield potential of multiple cropping is variable across regions, contingent upon the prevailing physical and socio-economic conditions.

Multi-tier cropping: The agricultural practice of cultivating various crops characterized by distinct heights, rooting structures, and growth durations is referred to as 'multi-tier cropping' or multi-storied cropping. This system of multi-storied cropping is predominantly observed in plantation crops such as coconut and arecanut. There exists an opportunity for intercropping within coconut plantations up to the age of 8 years and after 25 years. Throughout this interval, there is sufficient light penetration to the understory, thus facilitating the cultivation of intercrops. The primary aim of this cropping system is to optimize the utilization of vertical space. Within this framework, the leaf canopies of the intercrop components occupy disparate vertical strata. The tallest components possess foliage that is resilient to intense light and elevated evaporative demands, whereas the shorter component(s) feature foliage that necessitates shade and relatively high humidity, exemplified by combinations such as coconut + black pepper + cocoa + pineapple.

In this cropping system, coconut is established with a spacing of 7.5 m. Rooted cuttings of black pepper are positioned on either side of the coconut at a distance of approximately 75 cm from the trunk. At a height of about one meter above the ground level on the coconut trunk, the vines of pepper are directed to climb. A singular row of cacao is sown centrally within the inter-row spaces of the coconut. Pineapple is cultivated in the available interstitial spaces.

Coconut, which attains a height exceeding 10 m, occupies the uppermost tier. Black pepper, reaching a height of approximately 6-8 m, constitutes the secondary tier. Cacao, with its pruned canopy approximating 2.5 m in height, along with pineapple, which grows to about 1 m, form the first and ground tiers, respectively.

In a different multi-tier system associated with coconut, ginger or turmeric, alongside shade-tolerant vegetables, constitutes the initial tier, with banana occupying the second tier, pepper the third tier, and coconut or arecanut residing in the final tier.

Within arecanut plantations, tuber crops are predominantly utilized as intercrops. Elephant yam, tapioca, greater yam, and sweet potato are frequently cultivated as intercrops in humid tropical environments. Additionally, banana and pineapple are also grown as intercrops in arecanut gardens.

In the coffee-based multi-tier cropping system, the first tier is represented by pineapple, the second tier by coffee, the third tier by cacao or mandarin, and the final tier by rapidly growing shade trees essential for the coffee plantation, such as dadaps and silver oak.

Dairy Farming: Dairy farming constitutes a significant economic resource for agricultural practitioners. In addition to yielding milk and/or serving as draft animals, dairy livestock also provide a valuable source of farmyard manure, which acts as an organic matter enhancer for soil fertility. Furthermore, the byproducts generated on the farm are efficiently utilized for the nourishment of these animals. Despite the current estimates indicating that the overall milk production in the nation has surpassed the threshold of 90 million tons per annum, the per capita availability of milk remains approximately 220g/day, which is below the minimum requisite of 250g/day as advised by the Indian Council of Medical Research.

The dairy sector in India is characterized by a substantial population of animals yet exhibits markedly low productivity levels. Approximately 70% of Indian bovines and 60% of buffaloes demonstrate significantly low productivity rates. This sector is notably intensive in terms of livelihoods, providing supplementary income to over 70% of rural households and a considerable number of urban households. Moreover, this sector exhibits pronounced gender sensitivity, with over 90% of dairy enterprises being managed by women within the family unit.

Cattle Rearing: The practice of cattle rearing in India occurs under a diverse array of challenging climatic and environmental conditions. Cattle are broadly categorized into three distinct groups.

Draft breeds: The bullocks belonging to these breeds serve as competent draft animals, while the cows exhibit suboptimal milk production capabilities, for instance, Nagore, Hallikar, Kangeyam, and Mali.

Dairy breeds: The cows from these breeds are recognized for their high milk production, although the bullocks are characterized by inadequate draft capacity, examples include Sahiwal, Sindhi, and Gir.

Dual purpose: The cows in this category provide a reasonable milk yield while the bullocks possess commendable draft work capacity, such as Hariana, Ongole, and Kankrej.

Exotic breeds: The exotic breeds are distinguished by their high milk yield potential, e.g., Jersey, Holstein-Friesian, Aryshire, Brown Swiss, and Guernsey.

Buffaloes: The prominent dairy breeds of buffalo include Murrah, Nili Ravi (native to Pakistan), Mehsana, Suti, Zafarabadi, Godavari, and Bhadawari. Notably, the Godavari breed has emerged through the crossbreeding of local buffaloes in the coastal regions of Andhra Pradesh with the Murrah breed.

Housing: Each cow necessitates a spatial allocation of 12 to 18 square meters, while buffaloes require 12 to 15 square meters. It is imperative to ensure adequate ventilation, and an open shed is generally preferred for housing. Dairy facilities should be situated on elevated terrain to promote efficient drainage. The flooring should be textured and designed with a gradient of 2.5 cm for every 25 cm in length.

Breeding and maintenance: The lactation period for cows extends from 9 to 10 months, with an average interval between calvings ranging from 16 to 18 months. A cow typically necessitates a dry period of no more than 6 to 8 weeks. From an economic perspective, it is generally advisable to breed a cow during the second- or third-month following calving. In instances involving debilitated animals or those exhibiting high milk production, breeding may be deferred by an additional 1 or 2 months. Cattle exhibit estrous cycles that occur approximately every 21 days, with each cycle persisting for around one day. The optimal period for insemination of a cow is during the concluding phase of the estrous cycle. If utilizing artificial insemination, it is recommended to perform the procedure over a continuous span of 3 days to enhance the likelihood of conception. The duration of gestation exhibits variability among individual cows and breeds, with an average gestation period approximating 280 days.

In the context of buffaloes, the duration of the lactation period spans from 7 to 9 months. A female buffalo experiences estrus every 21 to 23 days. The gestation period for buffaloes is approximately 310 days. The rearing of calves is of paramount importance in the maintenance of buffaloes. Given their substantial requirement for water, provision for wallowing is essential. Routine deworming is also imperative for the effective management of buffaloes.

Under Indian environmental conditions, cattle typically achieve sexual maturity around the age of three years. However, this maturation period can potentially be abbreviated by six months with optimal herd management practices.

Goat and sheep rearing: The methodologies employed in the rearing of sheep and goats in India diverge significantly from those practiced in developed nations. Generally, smaller farming units are predominantly utilized, in contrast to the large-scale operations commonly found within fenced enclosures in developed countries.

Goat rearing: In the Indian context, the practice of goat husbandry is perpetuated across a diverse range of environmental conditions, encompassing arid, hot, humid, and frigid climates, as well as elevated mountainous terrains and low-lying plains. This practice is also intertwined with various systems such as agrarian or animal-based, pastoral or sedentary, singular animal or mixed herds, and operates on both small and large scales. The primary motivations for goat rearing include the production of meat, milk, hide, and skin. Notably, goat meat is regarded as the preferred source of protein within the nation. A live goat commands a superior market price compared to a live sheep.

Housing: Goats can be effectively maintained under stall-fed conditions. The success of goat husbandry is contingent upon the careful selection of an appropriate site. Goats do not flourish in marshy or swampy environments. It is imperative that goats are provided with a dry, comfortable, safe, and secure environment that is devoid of parasites and offers protection from extreme heat and adverse weather conditions. The young kids are sheltered under large inverted baskets until they reach an age sufficient to accompany their mothers. Typically, males and females are housed together. The spatial requirement for each goat is approximately 4.5 to 5.4 square meters.

Breeding and maintenance: Goats reach maturity within a span of approximately 6 to 7 months. Breeding is permissible for bucks at one year of age and for does after 10 months. The gestation period ranges from 145 to 155 days, yielding 1 to 3 kids per birthing event. The frequency of breeding events is typically three within a two-year timeframe. Kids can be weaned after 30 to 45 days. The mother may be permitted to mate 45 to 60 days post-birthing. To prevent the adverse effects of inbreeding, it is advisable to replace the buck every five years. Once the young goats attain a body weight of approximately 25 to 30 kilograms within nine months, they can be marketed.

Feeding: The nutrient requirements per individual goat are relatively modest. Consequently, goats are well-suited for resource-limited smallholders with marginal grazing availability. They are primarily browsers, consuming plant materials that are often overlooked by other livestock species. Goats typically ingest 4 to 5 times their body weight. Given that profitability is linked to weight gain, it is essential to provide goats with adequate levels of protein and calories. A significant proportion of their diet should consist of tree foliage; thus, 40 to 50% of the green fodder should comprise tree leaves, complemented by various grass species. Goats should be supplied with concentrated feed including maize, wheat, horse gram, groundnut cake, fish meal, and wheat bran. Additionally, common salt and vitamin supplements should be incorporated into their diet. Ample access to clean, fresh water is vital for goats, with water sources being replenished every morning and evening. Fresh water is essential for digestion, blood circulation, and the expulsion of waste materials from the body, as well as for the regulation of body temperature.

Sheep Rearing: Ovine species exhibit remarkable adaptability across a multitude of ecological niches. They serve as proficient gleaners, effectively utilizing substantial amounts of residual feed. Their dietary habits involve the consumption of significant quantities of roughage, thereby transforming an economically viable feed source into a lucrative cash crop. The requisite housing does not necessitate extravagance or high expenditure. Nevertheless, in order to safeguard the flock from potential predatory threats, it is imperative that the fencing be elevated to a height of two meters.

Breeds of Indian sheep: The ovine breeds found in India can be classified into three distinct categories, predicated upon the geographical delineation of the nation. The temperate Himalayan region encompasses: Gurez, Karanah, Bhakarwal, Gaddi, Rampur-Bushiar. The arid western region is represented by: Lohi, Bikaneri, Marwari, Kutchi, Kathiawari. The southern region includes: Deccani, Nellore, Bellary, Mandya, Bandur.

Breeding and maintenance: A single ram can be effectively maintained for a flock consisting of 40-50 ewes. Rams exhibit aggressive behavior when housed in proximity to one another within a confined space. In contrast to other agricultural species, ewes typically do not exhibit estrus at regular intervals throughout the year, instead displaying a seasonal pattern in this regard. The duration of the estrus cycle generally spans from 1-3 days, with approximately 75% of the ewes remaining in estrus for a period of 21-39 hours. The optimal timing for breeding occurs towards the conclusion of the estrus phase. The average interval between heat cycles is approximately 18 days during the breeding season. The gestational period varies from 142-152 days, with a mean duration of 147 days. A healthy ram reaches peak reproductive vigor between the ages of 2½ to 5 years. Ovine individuals achieve full growth by the age of two years, coinciding with the ewes' readiness for breeding. Under typical range conditions, ewes are expected to yield approximately five successive crops of lambs.

Feeding: An individual sheep necessitates an intake of approximately 1-2 kg of leguminous hay daily, which is contingent upon the age and body weight of the animal. Protein supplementation may be administered through concentrates such as groundnut cake, sesame cake, or safflower cake, particularly when pasture quality is deficient in legumes or during periods of scarcity. Generally, an intake of 110-225 g of cake suffices to sustain an average sheep in optimal condition. Additionally, the provision of a mixture comprising common salt, ground limestone, and sterilized bone meal in equal proportions is essential to mitigate mineral deficiencies present in the feed.

Piggery: The husbandry of pigs is primarily aimed at the production of pork. These animals are nourished with feeds that are deemed inedible, including forages, specific grain byproducts sourced from milling operations, damaged meat byproducts, and waste materials. The majority of these feed components are either unsuitable for human consumption or lack palatability. Pigs exhibit rapid growth and demonstrate a high reproductive capacity, typically farrowing between 10 to 12 piglets per event. Under optimal management conditions, a sow can produce two litters annually. The yield of carcass weight is substantial, ranging from 65% to 70% of the live weight.

Breeds: The utilization of imported breeds such as Large White Yorkshire and Landrace has become widespread. Among these, Yorkshire is recognized as the most commonly employed exotic breed within India. This breed is characterized by its prolific nature, superior carcass quality, impressive growth rate, and effective feed conversion efficiency. For a modest breeding enterprise, the selection of a herd boar is of paramount significance. An ideal boar typically attains a weight of approximately 90 kg within a span of 5 to 6 months and demonstrates robust physical structure in its limbs. The selected sow should exhibit the capacity to produce substantial litters, ideally comprising eight piglets or more.

Housing: The design of housing facilities must prioritize the comfort of pigs to ensure their optimal growth. It is imperative to eliminate conditions of dampness, drafts, and excessive heat. Locally sourced materials are permissible for the construction of housing. Each pig necessitates an area of approximately 2.7 square meters, accompanied by a wall height of 1.2 meters. A group of eight boars can be accommodated within an area ranging from 2.7 to 4.5 square meters, supplemented by an open space of 2.4 to 6.0 square meters.

Feeding: The provision of feed is critical to the successful rearing of pigs. Pigs, being the most rapidly growing category of livestock, are particularly susceptible to nutritional deficiencies in comparison to ruminants. A comprehensive diet for pigs should encompass proteins, carbohydrates, fats, minerals, vitamins, and an adequate supply of clean water. Given their simple stomach anatomy, pigs require a diet predominantly composed of concentrates with minimal roughage. The primary components of swine rations include cereals, millets, and their respective byproducts. To enhance feed utilization efficiency, the fiber content in swine rations should be maintained at a low level (approximately 5-6%). Additionally, mixed rations ought to incorporate 0.5% of added salt. Pigs necessitate a comparatively higher proportion of calcium and phosphorus than that required by cattle or sheep. When pigs are sustained on agricultural or kitchen waste, or on waste derived from fish and slaughterhouses, production costs can be significantly reduced. On average, feed consumption is estimated to be 3.5% of the total body weight. Feed allowances are typically calculated at 2.5 to 3.0 kg per 100 kg of body weight, in addition to 0.25 kg of feed per piglet for nursing sows.

Management: Generally, well-developed gilts weighing approximately 100 kg, at the age of 12-14 months, are deemed suitable for breeding purposes. The significance of body weight supersedes that of age in breeding considerations. Sows exhibiting low body weight have been associated with elevated rates of fetal and pre-weaning mortality and have demonstrated inadequate nursing capabilities. The average duration of the gestation period is approximately 114 days. The size of the litter at birth may range from 1 to 16 individuals, with individual body weights varying from 1 to 25 kg. The typical interval between the birth of piglets is 10 to 20 minutes. The entire duration of the farrowing process may extend from 1.5 to 4.0 hours. Sows are generally weaned after a period of 40 days. In commercial herds, it is beneficial to cull sows after their fifth or sixth litter. Weaned sows typically exhibit estrus within 3 to 10 days post-weaning and may then be permitted to breed. The recommended boar-to-sow ratio is 1:15. It is economically advantageous to produce two litters from each sow annually.

Mortality rates among piglets represent a significant source of economic loss, contributing to the decline of the pig industry. Generally, approximately one-fourth of piglets born do not survive to weaning. An additional one-tenth of piglets are classified as stunted or unprofitable due to disease or parasitic infections. Consequently, around 60-65% of piglets born reach a healthy state by slaughter age. The mortality rate is notably high during farrowing and the initial week subsequent to farrowing. The season in which farrowing occurs also influences mortality rates. The mortality of newborn piglet's peaks when farrowing coincides with extreme cold or heat. Therefore, it is imperative to schedule mating in a manner that avoids farrowing during such adverse climatic conditions.

Poultry: The poultry sector represents one of the most rapidly expanding food industries globally. Poultry meat constitutes approximately 27% of the total meat consumed worldwide, with consumption increasing at an average annual rate of 5%. The poultry industry in India is comparatively a nascent agricultural sector. Prior to 1950, it was primarily regarded as a backyard occupation in India. In the 1960s, the growth rate of egg production was approximately 10%, escalating to 25% in the 1970s. However, this growth rate diminished to 7-8% by 1990 due to rising poultry feed prices. By the year 2000, total egg production is projected to reach up to 5000 crores. Broiler production is experiencing an annual growth rate of 15%. The production of broilers was recorded at 31 million in 1981, rising to 300 million by 1995 (Singh, 1997). Currently, approximately 330 thousand tonnes of broiler meat are produced. The average global egg consumption is 120 eggs per person per year, whereas in India, it is merely 32-33 eggs per capita annually. According to nutritional recommendations, the estimated per capita consumption should be 180 eggs per year and 9 kg of meat per year**.**

Breeds: Particular poultry varieties for the purpose of egg and broiler production are readily accessible. A considerable proportion of the varieties employed in egg production are hybrids that encompass strains or inbred lines of the white Leghorn. To a lesser degree, alternative breeds such as Rhode Island Red, California Grey, and Australorp are utilized. Heavier breeds including white Plymouth Rock, White Cornish, and

New Hampshire are employed in the production of crossbred broiler chickens. Consequently, it is imperative to take into account the specific strain within the breed at the point of acquisition. Numerous commercial poultry breeders are engaged in the sale of day-old chicks within India. It is advisable to initiate the process with day-old chicks.

Housing: Sufficient space must be allocated for the avian subjects. An appropriate floor area of approximately 0.2 m² per adult bird is sufficient for lighter breeds like the white Leghorn. A range of 0.3-0.4 m² per bird is requisite for heavier breeds. The housing facility should ensure adequate ventilation, maintaining a temperate environment during summer while providing warmth in winter. Furthermore, it should be situated on well-drained terrain, safeguarded against floodwaters.

Feed: The feed conversion efficiency exhibited by poultry is markedly superior when compared to other livestock. Approximately 60-70% of the overall expenses incurred in poultry farming are attributed to the cost of feed. Therefore, the utilization of economical and effective rations will yield optimal profitability. The ration should be well-balanced, incorporating carbohydrates, fats, minerals, and vitamins. Among the prevalent feedstuffs employed in the formulation of poultry rations in India are:

Cereals: Maize, barley, oats, wheat, pearl millet, sorghum, and broken rice.

Cakes/meal: Oil cakes, maize gluten meal, fish meal, meat meal, and blood meal.

Minerals/salt: Limestone, oyster shell, salt, and manganese.

From the day-old stage up to four weeks of age, the birds are provided with a starter ration, followed by a finisher ration which is higher in energy content and contains 18-20% protein. Feeding may be administered 2-3 times throughout the day. In addition to the primary feedstuffs, antibiotics and pharmaceuticals may also be incorporated into the poultry ration. Laying hens should receive either oyster shell or ground limestone, with riboflavin being particularly essential.

Maintenance: It is critical that the chicks receive vaccination against Ranikhet disease using the F1 Strain vaccine within the initial 6-7 days of life. A single drop of the vaccine may be applied to the eye and nostril. Once the chicks attain an optimal body weight ranging from 1.0-1.5 kg at approximately six weeks of age, they become suitable for market as broilers. Hens may be retained for a duration of one year for production purposes, which corresponds to an age of about 1½ years, as egg production tends to diminish thereafter. An individual hen has the capacity to produce between 180-230 eggs annually, commencing at six months of age. Additionally, a laying hen generates approximately 230 grams of fresh droppings (with 75% moisture content) on a daily basis.

Duck rearing: Ducks constitute approximately 7% of the poultry demographic in India. They are especially favored in regions such as West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Tripura, and Jammu and Kashmir. The majority of ducks are of indigenous varieties and are primarily raised for egg production through natural foraging. These birds possess a production potential of approximately 130-140 eggs per bird annually. Ducks exhibit considerable hardiness, are relatively easier to brood, and demonstrate resistance to prevalent avian diseases. In environments characterized by marshy riversides, wetlands, and barren moors where chickens or other poultry species may struggle to thrive, duck rearing emerges as a more viable alternative.

Breeds: The notable Indian breeds include Sylhet Mete and Nageswari, which predominantly inhabit the Eastern sector of the nation. These breeds yield an annual production of around 150 eggs per bird. Enhanced breeds that are optimized for egg and meat production are also accessible. Among these, Khaki Campbell and Indian Runner stand out as the most favored breeds for egg laying. Khaki Campbell exhibits a remarkable production rate of 300 eggs per bird per year. Indian Runner ranks as the second most prolific producer. White Pekin, Muscovy, and Aylesbury are recognized for their meat production capabilities. Among these, White Pekin holds the title as the most sought-after duck globally, characterized by rapid growth rates and low feed conversion ratios, yielding high-quality meat. It achieves a body weight of approximately 3 kg within a span of 40 days. Nonetheless, indigenous breeds continue to dominate the landscape of duck farming. Desi ducks are robust, exhibit adaptability to local environmental conditions, and are resistant to diseases.

Housing: Ducks exhibit a preference for outdoor living both during the day and night, even amidst winter or rainy conditions. In temperate climates, it is feasible to raise ducks without the provision of artificial shelter. A minimal light fence, at least 1.2 meters in height, encircling the yard suffices to deter potential predators. One nesting unit measuring 0.3 x 0.3 x 0.45 meters is adequate for every three ducks. For laying birds, a mating ratio of one drake to six or seven ducks is recommended, while for meat-producing types, a ratio of one drake to four or five is permissible. The duck housing structure should be well-ventilated, dry, and impervious to leaves and rodents. The roofing may consist of thatched material or asbestos sheeting. A water channel measuring 0.5 meters in width and 0.20 meters in depth should be constructed at the far end on both sides, running parallel to the nighttime shelter within the rearing or layer house.

Feeding: Ducks typically necessitate minimal oversight. They enhance their diet through foraging, consuming fallen grains in harvested paddy fields, as well as small fish and other aquatic organisms in lakes and ponds. Nonetheless, for intensive farming practices, the provision of pelleted feed may be implemented. Ducks exhibit a preference for wet mash due to challenges associated with the ingestion of dry mash. Consequently, ducks should never be granted access to feed without concurrent access to water. During the initial eight weeks, the birds should be provided continuous access to feed. Subsequently, it is advisable to feed them bi-daily, specifically in the morning and late afternoon**.**

Maintenance: The overarching management practices for ducks exhibit notable similarities to those employed for chickens. The period of incubation spans 28 days. For small-scale hatching, a broody duck or hen may be utilized, whereas larger-scale hatching endeavors typically employ incubators. In the initial stages of life, newly hatched ducklings necessitate elevated temperatures, particularly under natural or village-based conditions. A single duck or broody hen is capable of caring for approximately 10 to 15 ducklings. For a substantial number of ducklings, artificial brooding methods may be implemented. High-yielding strains of ducks commence egg production at approximately 16 to 18 weeks of age. Ducks demonstrate a significant resilience to prevalent avian diseases. Common ailments affecting ducks include duck plague, duck virus hepatitis, duck cholera, and aflatoxicosis.

Apiculture: Apiculture encompasses both the scientific study and the cultural practices associated with honeybees and their management. It serves as a subsidiary occupation, providing an additional revenue stream for agricultural families. The practice necessitates minimal investment, thus rendering it accessible to smallholder, marginal, and landless farmers, as well as to educated unemployed youth.

Species: In India, two bee species are predominantly cultivated. These are *Apis cerana* indica and *A. mellifera*, which, while complementary to one another, exhibit distinct adaptations. *Apis cerana* is referred to as Indian bees, whereas *A. mellifera* is recognized as European or Western bees.

Apis cerana is primarily employed in commercial beekeeping across various regions of the country and is predominantly reared in ISI-A Type bee hives. This species demonstrates an instinctive propensity for swarming and absconding. Its honey production fluctuates between 12 to 15 kg per hive annually, with a foraging radius ranging from 0.8 to 1.0 km.

***Apis mellifera*:** This species has attained considerable success in the northwestern states of India. The width of its worker cell measures 5.3 mm, whereas the drone cell is 1 to 3 times larger. The average honey yield from this species ranges from 30 to 40 kg per hive annually, with a foraging distance that can extend up to 2 to 3 km.

Management: It is imperative for the beekeeper to possess knowledge regarding the sources of nectar and pollen present within their locality. The flora species that provide sustenance for bees are specific to various geographical areas and possess distinct micro-regional habitats. In the subtropical climates of India, nectar and pollen sources are available for a considerable portion of the year; however, a continuous succession throughout the year is absent in certain localities. Honeybees forage on flowers from numerous plant species to obtain nectar and pollen. The most significant sources of nectar and pollen include maize, mustard, sunflower, palm, litchi, pongamia, coconut, and sesame, among others. Beginners are advised to commence their beekeeping endeavors with a minimum of 2 and no more than 5 colonies. A minimum of 2 colonies is suggested to mitigate risks; in the unfortunate event of a mishap, such as the loss of a queen in one colony, the beekeeper may still benefit from the other colony.

The hive is composed of various components including the bottom board, brood chamber, brood chamber frames, super chamber, super chamber frames, top cover, inner cover, and entrance rod. These components can be easily disassembled. The hive may be constructed as either double-walled or single-walled. The single-walled hive is characterized by its lightweight and cost-effectiveness. The optimal period for initiating apiculture within a specific locality coincides with the onset of the swarming season. Swarming represents an inherent biological behavior of bees to partition their colonies under environmental conditions that are typically conducive to the survival of both the progenitor colony and the resulting swarm. This phenomenon transpires during the late spring or early summer.

Honey collection: Honey is a sweet, viscous substance synthesized by honeybees primarily from floral nectar. The quality of honey must adhere to both national and international standards. Attributes such as aroma, coloration, viscosity, and floral origins are of significant importance. Adequate straining and processing of honey are essential to enhance the quality of the final product. The composition of honey fluctuates in accordance with the variability in nectar derived from diverse plant species. The nectar gathered by bees undergoes processing and is subsequently stored in comb cells for the maturation process. During maturation, sucrose is enzymatically transformed into glucose and fructose by an enzyme known as invertase, which is introduced by the bees. Honey serves as an excellent source of energy, providing an average caloric content of approximately 3500 calories per kilogram. It is directly assimilated into the human bloodstream, thus negating the necessity for digestion.

Fishery: Ponds fulfill multiple beneficial roles, including serving as a domestic water supply, an auxiliary irrigation source for adjacent agricultural fields, and a medium for pisciculture. Through traditional management methods, farmers typically yield a mere 300-400 kg of both wild and cultured fish per hectare on an annual basis. Nevertheless, the implementation of composite fish culture with a stocking density ranging from 5000 to 7500 fingerlings per hectare, accompanied by supplementary feeding, can significantly enhance the overall biomass production.

Pond: The optimal depth of the pond should range from 1.5 to 2.0 meters. This specific depth facilitates effective photosynthesis and maintains suitable temperatures for the proliferation of zooplankton and phytoplankton. Clay soils exhibit superior water retention capabilities, rendering them ideally suited for aquaculture. The pond water must maintain an appropriate balance of nutrients, specifically phosphate (0.2-0.4 ppm), nitrate (0.06-0.1 ppm), and dissolved oxygen (5.0-7.0 ppm). The water should exhibit a slightly alkaline pH range of 7.5 to 8.5. Should the pH fall below 6.5, it can be adjusted through the periodic addition of lime at intervals of 2-3 days. Conversely, a higher pH level (greater than 8.5) can be mitigated through the incorporation of gypsum. The application of fresh dung may also contribute to the reduction of elevated pH levels in the water.

The soil composition of the pond should undergo rigorous testing for nitrogen (N) and phosphorus (P) content. In instances where nutrient levels are found to be deficient, nitrogenous fertilizers such as ammonium sulfate and urea, along with phosphatic fertilizers such as super phosphate, may be introduced. Additionally, organic amendments such as farmyard manure (FYM) and poultry droppings can be applied to stimulate the growth of phytoplankton and zooplankton.

Species of fish: Among the Indian major carps, Catla (*Catla catla*) is recognized as the fastest growing species. It exhibits a high rate of consumption of both vegetation and decomposing higher plant matter. Its feeding habits predominantly categorize it as a surface and column feeder. Rohu (*Labeo rohita*) primarily occupies the column of the water column and predominantly preys on smaller fish. Additionally, it consumes substantial amounts of vegetation and decomposing plant material. Its feeding behavior is chiefly associated with both column and surface feeding. Calbasu (*Labeo calbasu*) primarily engages in bottom feeding on detritus substrates. Mrigal (*Cirrhinus mrigala*), similarly, is a bottom feeder, extensively consuming detritus, diatoms, filamentous algae, and other higher plant forms.

Common carp (*Cyprinus carpio*) is classified as a bottom feeder and exhibits omnivorous dietary tendencies. Silver carp (*Hypophthalmichthys molitrix*) predominantly feeds at the surface level, primarily on phytoplankton, and also incorporates micro-plants into its diet. Grass carp (*Ctenopharyngodon idella*) is a specialist feeder, primarily targeting aquatic vegetation, cut grass, and other forms of vegetable matter. It is also noted for its rapid growth as an exotic species.

Composite fish culture: In a composite fish culture system, the phytophagous fish species, such as Catla, Rohu, and Mrigal, can be synergistically integrated with omnivorous species (Common carp), plankton-feeding species (Silver carp), and detritivore species (Mrigal and Calbasu).

Management: To enhance productivity, it is imperative to provide supplementary feeding to the fish utilizing rice bran and oilseed cakes. This practice facilitates accelerated growth and improved yield outcomes. Each variety of carp should be stocked at a density of 500 fingerlings, with an overall stocking capacity ranging from 5000 to 8000 per hectare. Such stocking density is conducive to achieving a maximum yield of 2000 to 5000 kg/ha of fish annually, contingent upon the implementation of effective management practices.

Sericulture: Sericulture is characterized as a systematic practice that integrates mulberry cultivation, silkworm rearing, and silk reeling processes. This practice has gained recognition within the Indian context. India holds the second position globally in silk production, following China. The total area dedicated to mulberry cultivation in the country spans approximately 188 thousand hectares. This sector significantly contributes to the socio-economic advancement of rural impoverished communities in certain regions. In India, over 98% of mulberry silk is produced in five traditional sericultural states, namely Karnataka, Andhra Pradesh, West Bengal, Tamil Nadu, and Jammu and Kashmir.

The climatic conditions prevalent in India are conducive to the vigorous proliferation of mulberry plants and the continuous rearing of silkworms throughout the annual cycle. The temperature range observed in Karnataka, which is a principal silk-producing state in India, fluctuates between 21.2 to 30 degrees Celsius. The climatic environment in Kashmir is particularly advantageous for silkworm cultivation from the months of May to October.

Moriculture: The cultivation of mulberry plants is referred to as 'moriculture'. Approximately 20 species of mulberry exist, of which four are predominantly cultivated. These species include Morus alba, M. indica, M. serrata, and M. latifolia. The mulberry crop can yield effectively for a duration of 12 years, subsequent to which the plants are removed, necessitating the implementation of fresh planting. The yield of mulberry leaves averages between 30 to 40 tons per hectare per annum.

Silkworm rearing: There are four distinct types of silkworms, namely: (i) Mulberry silkworm – Bombyx mori, (ii) Eri silkworm – *Philosamia ricini*, (iii) Tassar silkworm – *Antheraea mylitta*, and (iv) Muga silkworm – *Antheraea assamensis*.

Rearing and maintenance: The fertilized moth is encased within an inverted funnel or cellule, allowing the eggs to be deposited onto a cardboard substrate. Parasites may be eliminated by delicately brushing the egg masses with a fine brush, which also facilitates a uniform hatching process. A bamboo tray is lined with rice husk, to which tender, chopped mulberry leaves are added. The newly hatched larvae are then transferred onto these leaves. It is crucial to replace the leaves every 2 to 3 hours during the initial 2 to 3 days of the larvae's development.

The cocoon is constructed from a singular, reeling thread of silk. If the moths are permitted to emerge from the cocoons, the silk thread becomes fragmented. Consequently, the pupae are terminated 2 to 3 days prior to the emergence of the moths and subsequently processed. The cocoons designated for further rearing are segregated, allowing the moths to emerge from them in due course.

Mushroom Cultivation: Mushrooms represent a diverse group of edible fungi, exhibiting significant variation in morphology, dimensions, and pigmentation. Fundamentally, mushrooms are classified as vegetables cultivated within controlled agricultural environments characterized by stringent sanitation protocols. Analogous to other vegetables, mushrooms possess a moisture content of approximately 90% and are distinguished by their high-quality protein composition. Furthermore, mushrooms serve as a commendable source of vitamin C and B complex vitamins. The protein contained within mushrooms demonstrates a digestibility rate of 60-70% and encompasses all essential amino acids. Additionally, they are a rich source of vital minerals such as calcium, phosphorus, potassium, and copper. With a low fat and carbohydrate content, mushrooms are deemed beneficial for individuals managing diabetes and hypertension.

Species: Three predominant varieties of mushrooms are extensively cultivated in India. These include (i) Oyster mushroom – *Pleurotus spp*., (ii) Paddy straw mushroom – *Volvariella volvacea*, and (iii) White button mushroom – *Agaricus bisporus*.

Method of Production: Oyster Mushroom: Commence by procuring fresh paddy straw, which should then be segmented into smaller pieces measuring 3-5 cm in length. Subsequently, these pieces must be immersed in water for a duration of 4-6 hours, followed by boiling for thirty minutes. After draining the water, the straw should be dried in a shaded environment until achieving a balance that is neither overly dry nor excessively wet. Utilize polythene bags measuring 60 x 30 cm, ensuring to create two apertures, each with a diameter of one cm, positioned centrally and oriented towards opposing sides. Secure the base of the bag with a thread to establish a flat foundation. Fill the bag with paddy straw to a height of 10 cm, followed by inoculation with the spawn. Proceed to construct 4-5 alternating layers of straw and spawn, culminating with a final straw layer at a height of 10 cm. This assembly should be maintained in a spawn running room regulated at a temperature range of approximately 22-28°C and a relative humidity of 85-90%. Upon completion of the spawn running phase, typically after 15-20 days, the polythene bag should be incised and relocated to a cropping room, allowing for a growth period of 7 days prior to harvesting. The expected yield of mushrooms is approximately 0.5-1.0 kg per bag.

Paddy Straw Mushroom: The straw should be cut into elongated pieces measuring 60-90 cm, followed by immersion in water for 12 hours and subsequent sterilization for 15 minutes. The straw should then be organized into bundles, which are to be positioned on a slightly elevated concrete surface or wooden platform in layers comprising four bundles in width. The spawning process should occur simultaneously across all layers, either through broadcasting or by strategically placing the grain spawn at various locations. It is advisable to sprinkle grain dhal over each layer containing spawn, ensuring that spawning does not occur below the uppermost layer. The temperature must be maintained at 30-35°C. Harvesting is anticipated to be completed after 25-30 days, yielding approximately 1-1.5 kg per bed.

Button mushroom: Cultivation necessitates a sophisticated methodology for compost preparation, which serves as a substrate for mushroom cultivation. The inoculation process can be accomplished through three distinct techniques, namely surface spawning, layer spawning, and trough spawning. The trays must be filled with compost prior to the spawning process. Subsequent to spawning, the compost should be compressed diligently to achieve a compact structure. The trays are to be arranged in tiers within the cropping facility and covered with a newspaper sheet, which is treated with a 2% formalin solution. A temperature range of 20-25°C and a relative humidity of 90-95% must be sustained. Following the completion of spawn running within a timeframe of 15-20 days, casing is to be performed. The appearance of pinheads occurs within a period of 10-15 days post-casing. The cropping phase extends for a duration of 60-75 days. Harvesting of mushrooms can be conducted at the button stage, with yields typically varying from 6-7 kg/m².

Agroforestry: Agroforestry encompasses a comprehensive designation for land-use systems and methodologies in which woody perennials—such as trees, shrubs, palms, and bamboos—are intentionally integrated within the same land management unit as agricultural crops and/or livestock, either through spatial arrangements or temporal sequences.

In agroforestry systems, there exist ecological and economic interactions among the various components. This implies that:

Agroforestry typically incorporates two or more species of flora (or a combination of flora and fauna), with at least one species being a woody perennial. an agroforestry system invariably yields two or more outputs. the operational cycle of an agroforestry system extends beyond a single year. even the most rudimentary agroforestry system exhibits greater structural, functional, and socio-economic complexity when compared to monocropping systems.

Agroforestry plays a crucial role in fulfilling the fodder, fuelwood, and small timber requirements of farmers, while also contributing to the conservation of soil and water resources, maintenance of soil fertility, management of salinity and waterlogging, fostering positive environmental impacts, and providing alternative land-use options for marginal and degraded lands. The selection of appropriate land-use systems conserves the biophysical resources of non-arable land while simultaneously addressing the daily needs of farmers and livestock within the agricultural framework.

The various commonly practiced agroforestry systems in India include: (1) Agri-silviculture (crops + trees), commonly referred to as farm forestry; (2) Agri-horticulture (crops + fruit trees); (3) Silvi-pasture (trees + pasture + animals); (4) Agri-horti-silviculture (crops + fruit trees + multipurpose tree species + pasture); (5) Horti-silvi-pasture (fruit trees + multipurpose tree species + pasture); (6) Agri-silvi-pasture (crops + trees + pasture); (7) Homestead agroforestry (a diverse combination of various components); (8) Silvi-apiculture (trees + honey bees); (9) Agri-pisci-silviculture (crops + fish + multipurpose tree species); (10) Pisci-silviculture (fish + multipurpose tree species), among others..

Agri-silvicultural systems: This particular system underscores the cultivation of arboreal species alongside the agricultural production of field crops and/or fodder crops within the interstitial spaces between the trees. In arid and semi-arid regions, resilient tree species such as *Prosopis cineraria* (Khejri), *Eucalyptus sp., Acacia tortilis*, *Hardwickia binata* (Anjan), *Azadirachta indica* (Neem), *Ailanthes excelsa*, *Ziziphus jujuba*, among others, can be cultivated in conjunction with dryland crops, including pulses (such as pigeonpea and blackgram) and millets (like finger millet and sorghum). This practice is predominantly conducted on arable lands, wherein multifunctional trees, which serve purposes such as the provision of fuel and fodder, can be cultivated alongside crops within field settings as a method of alley farming. The hedges are designed to follow contour lines and incorporate trees and shrubs like Leucaena or pigeonpea. The utilization of leguminous perennials is particularly advantageous due to their capacity for nitrogen fixation.

Agri-horti-silviculture: Within this system, fruit-bearing trees are cultivated in conjunction with both crops and multifunctional trees (MPTs). In rainfed conditions, robust fruit trees such as ber, aonla, pomegranate, and guava can be grown alongside dryland crops, including pigeonpea, til, mothbean, and mustard. Grafted varieties of ber (e.g., Gola, Seb, Mundiya, Banarasi Kasak) may be established at a spacing of 6 x 6 m, with two subabul plants interspersed between them.

Under conditions of partial irrigation, species such as Guava, pomegranate, Lemon, and Kinnow have been successfully cultivated at a spacing of 6 x 5 m alongside crops like wheat, groundnut, and subabul (at a density of 200 plants per hectare) to facilitate rapid leaf fodder and fuel wood production.

To further safeguard fruit crops from the deleterious effects of desiccating hot summers and frigid winters, subabul or sesbania should be planted at intervals of 2 m to serve as windbreaks. Alternate harvests of subabul or sesbania can be executed every third year to yield quick fodder and fuel wood. The relative grain yield has been observed to range between 70-85% even in the third and fourth years.

Silvi-Pastoral system: In the silvi-pastoral system, enhanced pasture species are integrated with arboreal species. This system permits the simultaneous cultivation of grasses or grass-legume mixtures alongside woody perennials within the same land unit. The silvi-pastoral system has been identified as the most economically viable agroforestry approach, particularly in marginal, sub-marginal, and other degraded lands, especially within arid and semi-arid regions. It entails the lopping of trees and the grazing of understorey grasses and shrubs in both forests and plantations. This system contributes to the reduction of concentrated feed costs for livestock during periods of scarcity. A variety of fodder trees such as *Leucaena latisiliqua*, *Bauhinia variegata*, *Albizzia labbek*, *Albizzia amara*, *Moringa olerifera*, *Sesbania sesban*, *S. grandiflora*, and *Hardwickia binata* have been identified for various regions across the country in relation to silvi-pastoral systems. Trees provide essential fuel and timber resources during the extreme dry season and periods of scarcity, while animals graze on pastures and consume the foliage of nutritious trees and shrubs. The implementation of multilayered vegetative covers proves effective in mitigating runoff and preventing soil erosion in susceptible areas.

Horti-Pastoral System: This system encompasses the amalgamation of fruit-bearing trees with pastureland. Within the degraded arid and semi-arid rangeland ecosystems, one can observe a significant presence of overgrazed specimens of *Ziziphus nummularis*, which may be effectively budded with superior cultivars of ber (such as Gola, Seb, Umran, Banaras, Kaska), in addition to the planting of multi-purpose trees (MPTs) such as anjan, Subabul, and Khejri alongside various grasses and legumes including Cenchrus, Lasiurus, Chrysopogon, Stylosanthes, and Sirato.

Agri-silvi-pasture: This paradigm represents a synthesis of agri-silviculture and silvi-pastoral systems. In the arid and degraded terrains of Rajasthan, Gujarat, and Haryana, it is common to cultivate dryland crops such as bajra, moth, urad, and til in strip formations juxtaposed with grass strips to mitigate the encroachment of shifting sand onto cultivated areas. The introduction of MPTs is feasible both within the pasture strips and the crop strips, which, apart from shielding crops from the desiccating effects of extreme hot and cold winds, would additionally furnish leaf fodder, timber, and pasture during instances of crop failure. The woody flora could include Acacia senegal, ber, anjan, and neem, while the grasses might consist of Cenchrus, Lasiurus, and the legume Stylo spp.

Pastoral Silvicultural System: This system entails the practice of integrated crop farming to fulfill the forage and fodder requisites for livestock. The pastoral silvicultural system is characterized by grazing as the predominant activity, alongside the presence of sporadically distributed trees within the region. This methodology is prevalent in the semi-arid regions of India, encompassing the states of Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, and Madhya Pradesh.

Farmers typically allow their fields to remain fallow, preserving the existing trees and providing them with protection. *Dichanthium annulatum* is recognized as a significant grass species within this framework. The key planted arboreal species in this system include Eucalyptus hybrid, *Casuarina equisetifolia*, *Borassus flabellifer*, and *Phoenix sylvestris*. Typically, the trees are lopped to procure fuel and fodder. Fruits from custard apple, mango, Zizyphus, and tamarind are utilized for domestic consumption.

Biogas Plant: A biogas unit constitutes a valuable asset for agricultural households. It generates high-quality manure, provides a clean fuel source, and enhances sanitation conditions. Biogas is recognized as a clean, non-polluting, and economical energy source, obtainable through a straightforward mechanism and minimal investment. The gas is produced from cow dung via the process of anaerobic decomposition. The generation of biogas entails a complex biochemical procedure wherein cellulosic material is decomposed into methane and carbon dioxide by diverse groups of microorganisms. This biogas can be utilized for culinary purposes, illuminating lamps, and operating pumps, among other applications. Selection of a model: The primary configurations of biogas facilities encompass the floating gas holder and the fixed-dome variants. The advantages and disadvantages of each configuration must be evaluated during the model selection process.

Float dome type: Numerous models are present within this classification, such as the KVIC vertical and horizontal designs, the Pragati model, and the Ganesh model.

Fixed dome type: The gas facility is characterized by an underground dome-shaped construction. The masonry gas holder constitutes an essential component of the digester referred to as the dome. The gas generated within the digester is accumulated in the dome at vertical pressure through the displacement of slurry in the inlet and outlet. The entire structure is constructed using bricks and cement. The models available in this category include Janata and Deen-Bandhu. The choice of a specific type is contingent upon the technical, climatological, geographical, and economic conditions prevalent in a specific locality**.**

Selection of Size: The dimensions of the biogas facility are determined by the number of household members and the availability of dung. A biogas plant with a capacity of one cubic meter necessitates the presence of two to three animals and 25 kg of dung. The gas produced will suffice for the needs of a family comprising 4-6 individuals. A biogas plant with a capacity of two cubic meters would adequately serve the requirements of a family consisting of 6-10 members.

Site selection and management: The location should be in proximity to the kitchen or the point of usage. This proximity will diminish the expenses associated with the gas distribution system. Additionally, it should be situated near the cattle shed to minimize transportation costs for cattle dung. The land should be leveled and positioned slightly above ground level to prevent water inflow or runoff. The facility should receive unobstructed sunlight for the majority of the day.

The generation of dung has a direct correlation with the volume of gas produced. Gas production is significantly heightened during the summer months, followed by the rainy and winter seasons. Optimal gas production occurs at temperatures ranging between 30 to 35°C. When the ambient temperature declines below 10°C, gas production experiences a substantial reduction.

Biogas slurry: Slurry is derived following the generation of biogas. It serves as an enriched fertilizer. An additional beneficial characteristic of this fertilizer is that it does not attract fleas and worms, even after prolonged exposure to the atmosphere.

Conclusion

"Integrated Farming Systems" denote the comprehensive amalgamation of agricultural enterprises, including but not limited to, cropping systems, horticulture, animal husbandry, aquaculture, agroforestry, and apiculture, aimed at the optimal utilization of agricultural resources, thereby fostering prosperity among farmers. A carefully orchestrated combination of cropping methodologies alongside complementary enterprises such as fruit cultivation, vegetable production, floriculture, dairy farming, poultry, duck farming, pig husbandry, goat farming, aquaculture, and sericulture, tailored to specific agro-climatic conditions and the socio-economic profiles of farmers, has the potential to generate supplementary employment and income for smallholder and marginal farmers operating under both rainfed and irrigated environments.

With the limited prospects of expanding arable land, it becomes crucial to enhance agricultural output to cater to the burgeoning population in developing nations in the forthcoming years. Given the significant constraints on the horizontal expansion of land designated for agricultural activities, the sole viable alternative lies in vertical expansion and the augmentation of productivity across various farming enterprises. The concept of a farming system encompasses a multitude of factors including climate, soil, water, crops, agricultural waste, livestock, land, labor, capital, energy, and other resources, with the farm family positioned at the core, orchestrating agricultural and allied operations. Integrated Farming Systems are critically important for the proficient management of available resources at the farm level, facilitating the generation of sufficient income and employment opportunities for the rural impoverished populace, while concurrently enhancing their livelihoods in a sustainable manner. The synergistic interactions among the components of farming systems must be harnessed to improve resource-use efficiency and promote the recycling of agricultural by-products. This approach represents an efficacious method of utilizing the same land resource to concurrently or sequentially produce both carbohydrates and animal proteins, while simultaneously addressing vitamin and mineral deficiencies through the cultivation of vegetables and fruits on dykes and bunds, thereby furnishing a balanced diet for the farm family and mitigating hunger and malnutrition. The integration of aquaculture with livestock and crop production leads to optimized nutrient utilization through the recycling of by-products, effectively controlling weeds and certain insect pests; an ancillary benefit is the enhancement of a cleaner and healthier rural environment. Transitioning from the prevailing discipline-centric strategies to more holistic methodologies necessitate significant attitudinal shifts among policymakers, researchers, and development practitioners. In India, the Green Revolution was catalyzed by a 'gene revolution' that revolutionized the exploitation of genotypes, resulting in augmented input utilization. Nonetheless, the aspiration for a second Green Revolution in India and other developing nations is feasible through the implementation of a small farm revolution, achievable via innovative strategies such as Integrated Farming Systems.

References

Behera, U.K. and Mahapatra, I.C. (1999). Income and employment generation of small and marginal farmers through integrated farming systems. *Indian Journal of Agronomy*. **44**(3), 431-439.

Behera, U.K., Jha, K.P. and Mahapatra, I.C. (2004). Integrated management of available resources of the small and marginal farmers for generation of income and employment in eastern India. *Crop Research,* **27**(1), 83-89

Chuang, F.T. (1973). An Analysis of Change of Taiwan's cultivated land utilisation for recent years. Rural Economic Division JCRR Rep. 21, Taipei, Taiwan.

Collinson, M.P. (1987). Experimental Agricultural, **23**,385-386.

Dalrymple, D.F. (1971). *Survey of Multiple Cropping in Less Developed Nations*. USDFA, Washington, D.C. FEDS. p.108.

Dantzig, G.B. (1982). Reminiscences about the origin of linear programming. Operations Research Letters, **1**,43-48.

Dent, J.B. (1990). *Systems theory applied to agriculture and the food chain*. Elsevier, Amsterdam.

FAO (2001). *Farming Systems and Poverty, Improving Farmers' livelihoods in a changing World.* Food and Agriculture organization of the United Nations, Rome pp 412.

FAO (1990). *Women in Agricultural Development, Gender Issues in Rural Food Security in Developing countries.* FAO, Rome, Italy.

IOBC (1983). International organization for biological and integrated control. Technical bulletin 16 (1).

Jha, D. (2003). An overview of farming systems research in India. *Annals of Agricultural Research* 24(4),695-706.

Karmakar, N. (1984). A new polynomial time algorithm for linear programming. *Combinatorica*, **4**, 373- 395.

Kumar, S. and Jain, D.K. (2005). Are linkages between crops and livestock important for the sustainability of the farming system? *Asian Economic Review* **47**(1),90-101.

Lightfoot, C. (1990). Integration of aquaculture and agriculture, a route to sustainable farming systems. Naga, The ICLARM Quarterly 13(1),9-12.

Mahapatra, I.C. (1992). Farming systems research challenges and opportunities. *Eastern Indian Farming System Research & Extension, Newsletter* **6**(4),3-10.

Mahapatra, I.C. (1994). Farming system research – A key to sustainable agriculture. *Fertilizer News*, **39**(11) ,13-25.

Mahapatra, I.C. and Behera, U.K. (2004). Methodologies of farming systems research. Panda, D., Sasmal, S., Nayak, S.K., Singh, D.P. and Saha, S.(Eds), *Recent Advances in Rice-based Farming Systems*, 17-19 November 2004, Cuttack, Orissa, Central Rice Research Institute, pp79-113.

Menegay, M.R., Hubbel, J.N. and William, R.D. (1978). Crop intensity index, a research method of measuring land use in multiple cropping. *Horticultural Science* **13**, 8-11

Rangaswamy, A, Venkataswamy, R., Premsekhar, M. and Palaniappan, S.P. (1992). Sustainable agriculture for rice (*Oryza sativa*) based ecosystem, *Indian Journal of Agronomy,* **37** (2), 215-219.

Rangaswamy, A. Venkitaswamy R. Purushothaman and Palaniappan, Sp. (1996). Rice-Poultry–Fish–Mushroom integrated farming systems for lowlands of Tamil Nadu– *Indian Journal of Agronomy,* **41**(3), 344-348.

Rath, R.K. (1989). Integrated fish farming system in China, An analytical Review. Fishing Chimes (Sept. issue),20-27.

Rautaray, S.K., Das, P.C., Sinhababu, D.P., Sinhababu, D.P and Singh, B.N. (2004). Increasing farm income through rice-fish based integrated farming system in rainfed lowlands of Assam. *Indian Journal of Agricultural Sciences* (Communicated).

Rhoades, R.E. and Booth, R.H. (1982). Farmer-back-to-back farmers, a model for generating acceptable agricultural technology. *Agricultural Administration,* **11,** 127-137.

Shaner, W.W., Philipp, P.F. and Schmehl, W.R. (1982). *Farming Systems Research and Development, Guide for Developing Countries*. West View Press, Colorado, USA.

Sharma, A.R. and Behera, U.K. (2004). Fertiliser use and option for diversification in rice-wheat cropping systems in India. *Fertiliser News,* **49**(12),115-131.

Singh, A.K. (2001). Farming system and its sustainability with reference to ground water resource use in Uttar Pradesh (unpublished paper)

Singh, Kalyan, Bohra, J.S., Singh, Y. and Singh, J.P. (2006). Development of farming system models for the north-eastern plain zone of Uttar Pradesh. *Indian Farming,* **56**(2), 5-11.

Singh, S.S. (1997). Crop Management under irrigated and rainfed conditions. Kalyani Publishers, Ludhiana, India.

Yates, C.M. (2000). Modelling consequences of new reproductive technologies in the bovine sector of U.K. Agriculture. Ph.D. Thesis, The University of Reading, Reading, U.K.

Zandstra, H.G. *et al.* (1981). A methodology for on-farm cropping systems research, IRRI, Los Banos, Philippines.

Zandstra, H.G. (1978). Cropping systems Research for the Asian Rice farmers'. *Agricultural Systems.* **4,** 135-153.