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# SUSTAINABLE INTEGRATED FARMING SYSTEMS FOR DRYLANDS - A REVIEW

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## ABSTRACT

The traditional cropping leads to a high degree of uncertainty in yield, income and employment under dryland conditions. The integrated farming systems approach introduces a change in the farming techniques for maximum productivity in farming by optimal utilisation of resources. Judicious mix of agricultural crops and other enterprises suited to the given agroclimatic condition and socio-economic status of the farmer would improve the prosperity in the dryland farming. The present day trend towards sustainable agriculture encourages the utilisation of residue and waste materials of crop and its allied activities for enrichment of soil nutrients, water retention to protect the environment over a long period. In this treatise, relevant literature on farming systems research, contribution of different components in the farming system under drylands are briefly reviewed.

## Climate, soil and productivity of crops in dryfarming regions

Drylands are characterised by highly fragile resource base and mainly depends upon the prevailing weather conditions. Among them, rainfall is the major deciding factor. Erratic and uneven distribution of rainfall coupled with high rates of evaporation in dry climate often lead to periods of water scarcity and have serious implications for stability and sustainability of crop production (Aggarwal and Kumar, 1993). Singh (1995) opined that the total rainfall, its distribution, potential evapotranspiration and soil water storage govern the length of growing season which varies from 60 to 300 days. He also stated that the important soil groups are vertisols and alfisols and their associated orders, which are characterised by low organic matter and poor nutrient status particularly with nitrogen, phosphorus, sulphur and calcium under drylands. The main constraints that limit crop production in drylands are moisture and nutrient stress. Lower nutrients status of soil and low water holding capacity also lead to poor crop yields in dry farming regions.

Present farming systems in the dryland area are characterised by low and unpredictable yield due to inefficient use of rain water, poor management of the soil, rare use of fertilizers, non adopting high yielding varieties and improved soil conservation techniques (Pathak and Laryea, 1995). Efficient resource management including improved water resource management, newly developed crop production technologies and alternate land use systems are the key issues to increase the productivity of the dryland areas (Singh. 1995).

## Farming systems research

'Farming' is a process of harnessing the solar energy in the form of economic plant and animal products. 'System' implies a set of interrelated practices and processes organised into functional entity i.e., an arrangement of components or parts that interact according to some process and transforms inputs into outputs (Fresco and Westphal, 1988).

According to Singlachar (1987), the farming system approaches for finding a solution should be diverse enough to find various alternatives with ecological relevance. According to Lal and Miller (1990), farming system is a resource management strategy to achieve economic and sustained production to meet diverse requirement of farm household while preserving resource base and maintaining a high level environmental quality. Farming system designates a set of agricultural activities

organised into a functional unit(s) to profitably harness solar energy while preserving land productivity, environmental quality and maintaining desirable level of biological diversity and ecological stability (Rangasamy, 1994).

**Integrated farming system**

Integrated farming system is a component of Farming System Research, deals with whole farm approach to minimise risk and increase the production and profit with better utilisation of wastes and residues. A judicious mix of agricultural enterprises like dairy, poultry, piggery, fishery, sericulture, forestry etc, suited to the given agroclimatic conditions and socio economic status of the farmers would bring prosperity in the farmings (Palaniappan, 1994). Balakrishnan (1994) stated that integrated farming system approach introduces a change in the farming techniques for maximum production in the cropping pattern and takes care of optimal utilisation of resources. Farming systems research has found acceptance as an effective approach to agricultural research and development and it considers the farmers total farming system which contrasts with the single crop/resource oriented research (Venkatadri, 1993). Maji (1991) opined that the study of farming system needs to be based on small agroecological zones, which are homogeneous at least with respect to endowments of natural resources, cropping pattern and socio-economic situation.

**Contribution by components in integrated farming system**

**Economic contribution:** Small ruminants like goats and sheep form an important economic and ecological niche in Asian mixed farming systems. Approximately 60 per cent of goats and 20 per cent of sheep population are found in Asia (Devendra, 1998). Oberoi *et al.* (1992) stated that goats were more remunerative than sheep in India. Prasad (1992) reported that the integration of livestock with land use systems increased the farm income. Deoghare and Bhattacharya (1993) also reported that the goats and sheep provide a most valuable source of income in drylands, moreover the sale of goats contributed 30.1 per cent of the total farm income in India. Similarly Wimalasuriya *et al.* (1993) also reported that in Sri Lanka, with minimal disturbance to the socio economic environment, the farmers with crop and livestock integration could earn an average of 88 per cent more income than farmers without livestock.

Prabaharan *et al.* (1994) also reported that goats generated higher annual income than dairy cattle and sheep and showed the best economic viability. Chinnaswami (1994) reported that integrated farming system with goat rearing produced an additional income of Rs.3258 and Rs.11,932 over farmers with only cropping system at Paiyur and Aduthurai areas of Tamil Nadu respectively. In the rainfed black soils of Aruppukottai, (Tamil Nadu) introduction of tree legumes like *Leucaena leucocephala* (Subabul), *Acacia Senegal* (Gum arabic tree), *Prosopis cineraria* (Khejri) and perennial fodder grass with inclusion of goat rearing yielded an additional income of Rs.2163 to Rs.2556 per year from a farm area of 1.6 ha (Veerabadran, 1994). He also reported that the integrated farming system with crop + horticulture + goat proved to be more successful and increased the profit by Rs.2163 to Rs.5206 per hectare over cropping system alone. Sivasankaran *et al.* (1995) reported that integrating crops, goat and trees recorded an additional net income of Rs. 3747 $ha^{-1}$ $yr^{-1}$ over conventional cropping alone.

Santhi *et al.* (1996) reported that highest benefit cost ratio of 1:1.28 was obtained with crop and livestock integration than cropping alone. Goat rearing was an appropriate intervention in a capital scarce situation and that can contribute significantly to household income (Saadullah *et al.*, 1997).

Among the main occupation of households, the average net income per household per year from livestock farming was 26.6 per cent and from crop farming it was 73.3 per cent (Deoghare, 1997). In an integrated silvipastoral based farming system for drylands, 18.63 t $ha^{-1}$ of grass legume fodder production was obtained and rearing goats recorded higher income followed by milch animal (Vairavan *et al.*, 2000). According to Gajja *et al.* (1999). the Benefit Cost Ratio was maximum with hortipasture system followed by silvipasture system.

**Employment generation:** Round the year gainful provision of employment is possibly one of the major considerations for evolving any cropping system. Dryland farm families remain unemployed for almost two thirds of the time. Change in crops and cropping pattern may be such one way of generating additional employment. Integrated farming system under dryland with sorghum + cowpea, *Leucaena leucocephala + Cenchrus ciliaris* (Kolukkattai grass), *Acacia Senegal +* grasses with goat rearing generated an additional employment of 113 man days $ha^{-1}$ annually (Sivasankaran *et al.*, 1995).On the other hand, Santhi *et al.* (1996) reported that the employment generation of 320 man days per year may be generated through Integrated farming system approach which was higher than the farmer's own crop raising system due to low cropping intensity. Singh (1996) reported that highest labour employment of 58.3 per cent was recorded in goat rearing with large flocks especially on grazing. According to Deoghare (1997), the average labour employment per household per year from goat, sheep, buffalo and crops farming were 23.3, 1.9, 33.1 and 41.5 per cent, respectively in Uttar Pradesh. Integrated farming system study at Bhubaneshewer for a period of two years comprising with field and horticultural crops, fishery, poultry, duckery, apiary, mushroom, dairy and agroforestry generated an additional employment of 573 man days on a small piece of land of 1.25 ha (Behera and Mahapatra, 1999).

**Resource (waste) recycling:** Nutrient cycling refers to transfer of nutrients from one component to another in the soil-plant-animal-environment system. Nutrient transfer occurs through livestock, if they are an integral part of the systems (Rao *et al.*, 1999). Continuous dairy based farming system increased the organic, humic and fulvic carbon and available N, extractable K, Ca and Mg, Zn, Mn, Fe with time (Das and Singh, 1992). Rangasamy (1994) opined that integration of enterprises like cattle rearing, fishery, poultry and goat rearing, sericulture and mushroom cultivation with cropping could properly recycle of the residues of different enterprises for getting maximum compatibility and replenishment of organic matter. The integrated farming system provides excellent opportunity for organic recycling, moreover, and it reduces farmers dependency on external or market purchased inputs. It offers good scope for recycling of crop components to the animals and vice versa (Vairavan *et al.*, 2000).

**Enrichment of soil:** *Leucaena leucocephala* with cereal intercropping improved the soil organic carbon status and available N and P but reduced the available K and Ca (Rawat and Hazra, 1991) under dryland condition. Arable crops like castor and redgram could be grown with *Acacia albida* in marginal lands under rainfed conditions with the advantage of enriched site due to the deciduous nature of the tree species (Bheemaiah *et al.*, 1992). Highest net return per hectare was obtained when sorghum or cowpea were grown in association with *Faidherbia albida* whereas the lowest with sole annual crops (Suresh and Rao, 1998). Further, Suresh and Rao (2000) reported that eight to nine years old nitrogen fixing tree species of *F. albida,*

*Acacia ferrugienia* (Parambi) and *Albizia lebbeck* reduced the seed and dry fodder yields of cowpea than sole crop whereas the fertilizer nitrogen application produced significantly higher seed and dry fodder yields.

**Alternate land use system**

For providing stability and sustainability to the farming system, tree cum crop farming system will be the most appropriate one. Alternate land use system is a perennial system or practice adopted to replace or modify the traditional land use (Singh and Osman, 1995). Subbian (1999) stated that alternate land use systems are appropriate in areas where subsistence farming is practised in fragile ecosystems and it posses more potentiality and flexibility in land use than the traditional crop production systems.

**Agroforesty**

Agroforestry is a part of alternate land use system. According to Lundgren and Raintree (1982), it is a collective name of land use systems and technologies, where woody perennials are deliberately used from the same land management units as agricultural crops and or animals in any form of space arrangement or temporal sequence.

Rao (1989) and Rao and Mac Dicken (1991) mentioned that, the term agroforestry encompasses any and all techniques that attempt to establish or maintain both forest tree and agricultural production on the same piece of land. Deb Roy (1995) reported that agroforestry is an integrated self sustained land management system, which involves woody perennials with agricultural crops including pasture/livestock simultaneously or sequentially on the same unit of land and meeting ecological as well as socio economic needs of the people. According to Sivakumar *et al.* (2000), due to low initial cost and ensured seasonal income through intercropping and supply of different kinds of raw materials to support cottage industries, tree farming in drylands would certainly offset the risky farming under dryland condition.

**Agrisilvicultural system:** *Prosopis cineraria* (khejri) is more suitable than *Acacia tortilis* (Israeli Babool) and *Tecomella undulata* (Teak) with cluster bean, cowpea and mothbean whereas *A. tortilis* may not be considered suitable for agroforestry because of crop failure (Jindal *et al.*, 1990). According to Deb Roy and Gill (1991), the best grain production (80-82 per cent relative yield) of sorghum, wheat, gram and arhar was recorded in association with *Casuarina equisetifolia* (Saru), *Emblica officinalis* (Aonla) and *Eucalyptus tereticornis* (The mysore gum) compared to 79 per cent relative yield in association with *Leucaena and Acacia nilotica* (Babul). Yield of sorghum was at par with sole sorghum when grown in tamarind, neem and silk cotton, whereas the yield was drastically reduced with *Ailanthus* (Mahrukh or Perumaram) and *Casuarina* (Anonymous, 1993). Dhyani and Tripathi (1999) reported an increase in yield as the distance from the tree increased. The tree growth *viz.*, height and collar diameter were more in agroforestry than in sole tree plantings (Deb Roy and Gill, 1991). Better growth and timber volume in the tree + crop situation was mainly due to the application of fertilizers and weeding to the rainfed crops (Dhyani and Tripathi, 1999).

**Agrihorticultural system:** Maize, sorghum and cowpea were observed more compatible with trees *(Psidium guajava, Eugenia jamolana* and *Annona squamosa)* and there was least reduction in the growth of trees and yield of crops (Dasthagir and Suresh, 1990). Khanna (1994) reported that the total productivity per unit area was the highest in guava + ber model followed by *E. officinalis*+ guava. He also reported that the productivity in terms of fruit and fodder was higher with *E. officinalis+ Leucaena leucocephala* as compared to guava + *Leucaena leucocephala*

model. In an agrihorticultural system i.e., citrus and wheat, maximum production of wheat was recorded during the establishment year of citrus species but, the production was reduced in the subsequent years (Gill *et al.*, 1999). Singh *et al.* (1999) reported that maximum height, collar diameter and biomass production were attained by *E. officinalis* as compared to *Hardwickia binata.*

In Northern hill region under moderately slopped land, horticultural crops increased the Ca, K and P content of the soils (Prasad, 1992). Newaj *et al.* (1999) reported that the organic carbon content of the soil was increased from 65 to 109 per cent below the canopy of *E. officinalis,* when compared to open canopy due to falling of leaves under rainfed condition. According to Arora and Mohan (1990), fruit based cropping systems not only are known for their economic viability but also generated the employments and gave assurance against crop failure during drought years. Under rainfed conditions of alfisol, agrihorticulture system gave the highest benefit cost ratio of 2.16 compared with 1.95 with annual cropping, 1.69 with agroforestry and 1.52 with agrisilviculture (Das *et al.*, 1993). Gill *et al.* (1997) reported that agrihorticultural system with mango + wheat with *Leucaena leucocephala* between mango trees was a successful system in Jhansi.

Silvi/Hortipastural system: Hortipasture is one of the agroforestry systems which involves integration of fruit trees with pasture. When a fruit tree is replaced with a fodder tree, it is called as silvipastoral system (Singh and Osman, 1995). *C. ciliaris* is a drought hardy, vigorously growing pasture species capable of producing good quality forage in arid and semi arid areas of India (Rajora, 1998). According to Mishra *et al.* (1997), *Cenchrus glaucus* (blue buffel grass) (CO 1 grass) at the flowering stage could meet the maintenance protein needs of sheep when offered as the sole feed.

The forage yield from *P. cineraria* was the highest, whereas it was the lowest by *A. Senegal* (Sharma *et al.*, 1980). In a hortipastural study, stylo and deenanath were compatible fodder crops with guava, custard apple and mango upto two years after planting (Sekar *et al.*, 1998). Singh and Osman (1995) also reported that after 18 months pasture establishment, survival and growth of fruit trees were found to be poor with grasses than association of legumes. In a silvipastoral system, the least survival was obtained with *Ailanthus excelsa* whereas maximum with *P. cineraria* (Singh *et al.*, 1996). In the same study maximum biomass production was obtained with *Cenchrus setigerus* (black kolukkattai grass) while minimum was recorded with *Panicum* sp. Jha (1990) reported that silvipastoral system with napier grass and *L leucocephala* increased the organic carbon and available K content of the soil (0.49 per cent and 46 kg $ha^{-1}$, respectively) compared to the initial stage level of 0.40 and 29 kg $ha^{-1}$, respectively after three years. Prasad (1992) stated that in the North eastern hill regions of India, silvipastoral crops were recommended for the moderately sloped lands which increased the Ca, K and Bray's P content. Robertson *et al.* (1993) reported that the total soil N and organic C were higher under permanent pasture than under sorghum. *L. leucocephala* with *Cenchrus + Stylosanthus* improved the organic carbon and available N and phosphorus content of the soil compared to the bare lands (Yadava and Varshney, 1997 and Katyal *et al.*, 1998).

Sankaranarayanan *et al.* (1987) reported that higher return was obtained from silvipastoral system of *A. tortilis* with *C. ciliaris* compared to growing pure tree or pure grass. According to Gajja *et al.* (1999) the silvipasture and hortipasture systems were more profitable than arable farming and the BCR was maximum under hortipasture followed by

silvipasture. In southern zone of Tamil Nadu, the gross income and B:C ratio obtained from sorghum + tamarind, sorghum + neem, black gram + neem, black gram + tamarind were found sustainable (Gururajan, 1999).

The available literature clearly reveals that the productivity and income under dryland situation could be stabilised by adopting integrated farming systems. Due to diverse ecological situation and socio-economic status, there is a need to develop farming systems suitable to the specific situation. It is also clear from the review that trees, perennial grasses and animal component could sustain the productivity and soil fertility of the system under drylands.

## REFERENCES


Aggarwal, R.K. and Kumar, P. (1993). *In* : Proc. Int. Symp. Environmental Degradation. CAZRI, Jodhpur, p. 21.

Anonymous (1993). Annual report, CRIDA, Hyderabad, p.67-75.

Arora,Y.K. and Mohan, S.C. (1990). *In* : Proc. Int. Symp. Water Erosion, Sedimentation and Resource Conservation, CSW CRTI, Dehradun, p.25.

Balakrishnan, R. (1994) *In* : Summer Institute on Integrated Farming System Research and Management for Sustainable Agriculture. Tamil Nadu Agric. Univ., Coimbatore, 6-15 June, 1994. p. 174-182.

Behera, V.K. and Mahapatra, I.C. (1999). *Indian J. Agron.*, **44**: 431-439.

Bheemaiah, G. *et al.*, (1992). *Ann. Arid Zone*, **31**: 303-304.

Chinnaswami, K.N. (1994). *In* : Summer Institute on Integrated Farming System Research and Management for sustainable agriculture., Tamil Nadu Agric. Univ., Coimbatore, 6-15 June, 1994. p.252-257.

Das, M. and Singh, B.P. (1992). *In* : Proc. Int. Symp. Nutrient Management for Sustained Productivity. Punjab Agric. Univ., Ludhiana. p. 62-64.

Das, S.K. *et al.* (1993). *Am. J. Alternative Agric.*, **8**: 34-39.

Dasthagir, M.G. and Suresh, K.K. (1990). *Myforest*, **26**: 8-12.

Deb Roy, R. (1995). *In* : Agroforestry Principles and Practices. Sustainable Development of Dryland Agriculture in India. (Singh, R.P. ed.) Scientific Pub., Jodhpur, p.399-413.

Deb Roy, R. and Gill, A.S. (1991). *Range Mgmt. Agroforestry*, **12**: 69-78.

Deoghare, P.K. and Bhattacharya, N.K.(1993). *Indian J. Anim. Sci.*, **63**: 439-444.

Deoghare, P.R. (1997). *Indian J. Anim. Sci.*, **67**: 916-919.

Devendra, C. (1998). *Ann. Arid Zone*, **37**: 215-232.

Dhyani, S.K. and Tripathi, R.S. (1999). *Agroforestry Systems*, **44**: 1-12.

Fresco, L.C. and Westphal, E. (1988). *Expl. Agric.*, **24**: 399-419.

Gajja, B.L. *et al.* (1999). *Ann. Arid Zone*, **38**: 173-180.

Gill, A.S. *et al.* (1997). *Indian Fmg.*, **47**: 25-28.

Gill, A.S. *et al.* (1999). *Indian J. Agron.*, **44**: 440-443.

Gururajan, B. (1999). *In* : Training Course on Resource Management for Sustainable Agriculture. Tamil Nadu Agric. Univ., Coimbatore, 17 Feb. - 2nd Mar., 1999. p. 92-97.

Jha, L.K. (1990). *In* : Environment Assessment and Management through Social Forestry in Tribal Region. Mandelian Society of India and Ranchi. B.A.U.

Jindal, S.K. *et al.* (1990). *Ann. Arid Zone*, **29**: 145-146.

Katyal, J.C. *et al.* (1998). *In* : Red and Lateritic soils. Vol.1. Managing Red and Lateritic Soils for Sustainable Agriculture, p.353-365.

Khanna, S.S. (1994). *J. Indian Soc. Soil Sci.*, **42**: 498-508.

Lai, R. and Miller, F.P. (1990). *In* : Sustainable Farming for Tropics. Sustainable Agriculture : Issues and Prospectives. Vol. I. (Singh, K.N. and Singh, R.P. ed.) Indian Society of Agronomy, IARI, New Delhi, p. 69-80.

Lundgren, B.O. and Raintree, J.B. (1982). *In* : Agricultural Research and Development Potential and Challenges in Asia Bnestel (ed.) ISMAR, *The Hague*, p.37-49.

Maji, C.C. (1991). *Indian J. Agric. Econ.*, **46**: 403-411.

Mishra, A.S. *et al.* (1997). *Indian J. Anim. Nutrition*, **14**: 250-253.

Newaj, R. *et al.* (1999). Annual Report, NRCA, p.44-47.

Oberoi, R.C. *et al.* (1992). *Livestock Advisor*, **17**: 25-30.

Palaniappan, S.P. (1994). *In* : Summer Institute on Integrated Farming System Research Management for Sustainable Agriculture. Tamil Nadu Agric. Univ., Coimbatore, 6-15 June, 1994. p. 18-38.

Pathak, P. and Laryea, K.B. (1995). *In*: Sustainable Development of Dryland Agriculture in India. (Singh, R.P. ed.) Scientific Publishers, Jodhpur, p. 83-92.
Prabaharan, R. *et al.* (1994). *Cheiron*, **23**: 221-229.
Prasad, R.N. (1992). *In*: Proc. Int. Symp. Nutrient Management for Sustained Productivity. Punjab Agric. Univ., Ludhiana. p.127-128.
Rajora, M.P. (1998). *Ann. Arid Zone*, **37**: 99-101.
Rangasamy, A. (1994). *In*: Summer Institute on Integrated Farming Systems Research and Management for Sustainable Agriculture. Tamil Nadu Agric. Univ., Coimbatore, 6-15 June, (1994). p. 1-7.
Rao, M.R. *et al.* (1999). *Ann. Arid Zone*, **38**: 275-307.
Rao, Y.S. (1989). *Forest News (Tiger Paper)*, Thailand, p.1-9.
Rao, Y.S. and Mac Dicken, K.G. (1991). *In*: Agroforestry in Asia and Pacific, (Mellick, W. *et al.*, eds.) RAPA Publication. p. 1-2.
Rawat, L.R. and Hazra, C.R. (1991). *Range Mgmt. and Agroforestry*, **12**: 195-200.
Robertson, F.A. *et al.* (1993). *Aust. Agric. Res.*, **44**: 1323-1336.
Saadullah, M. *et al.* (1997). *In*: Proc. Workshop on Integrated Farming in Human Development. Tune Landboskole, Denmark, 25-29 Mar. 1997. p.308-331.
Sankaranarayanan, K.A. *et al.* (1987). *Agroforestry Systems*, **5**: 69-88.
Santhi, P. *et al.* (1996). *Fmg. Systems*, **12**: 22-25.
Sekar, I. *et al.* (1998). *Madras Agric. J.*, **85**: 183-185.
Sharma, S.K. *et al.* (1980). *Ann. Arid Zone*, **19**: 283-287.
Singh, F. *et al.* (1996). *Indian J. Small Ruminants*, **2**: 33-37.
Singh, G. *et al.* (1999). *Range Mgmt. Agroforestry*, **20**: 26-33.
Singh, M.R. (1996). *Indian J. Small Ruminants*, **2**: 11-16.
Singh, R.P. (1995). *In*: Sustainable Development of Dryland Agriculture in India. (Singh, R.P. ed.) Scientific Publishers, Jodhpur, p. 13-23.
Singh, R.P. and Osman, M. (1995). *In*: Sustainable Development of Dryland Agriculture in India. (Singh, R.P. ed.) Scientific Publishers, Jodhpur, p. 375-398.
Singlachar, M.A. (1987). *In*: Agrarian Structure and Strategies for Agricultural Development for the 21st Century, **47**: 13-16.
Sivakumar, K.M. *et al.* (2000). *LEISA INDIA Suppl*, **2**: p.7.
Sivasankaran, D. *et al.* (1995). *Madras Agric. J.*, **82**: 458-460.
Subbian, P. (1999). *In*: Training Course on Resource Management for Sustainable Agriculture. Tamil Nadu Agric. Univ., Coimbatore, 17 Feb. - 2 Mar., 1999.
Suresh, G. and Rao, J.V. (1998). *Range Mgmt. Agroforestry*, **9**: 33-41.
Suresh, G. and Rao, J.V. (2000). *Expt. Agric.*, **36**: 41-50.
Vairavan, K. *et al.* (2000). *The Hindu*, 27-4-2000.
Veerabadran, V. (1994.) *In*: Summer Institute on Integrated Farming System Research and Management for Sustainable Agriculture. Tamil Nadu Agric. Univ., Coimbatore. 6-15 June, 1994. p. 258-269.
Venkatadri, S. (1993). *J. Rural Reconstruction*, **26**: 33-42.
Wimalasuriya, R.K. *et al.* (1993). *J. Asian Fmg. Systems Assoc.*, **2**: 29-44.
Yadava, R.B. and Varshney, R.B. (1997). *Range Mgmt. Agroforestry*, **18**: 195-200.