REVIEW OF LITERATURE

Cropping Pattern:

The subject of cropping pattern is much broader than the word "rotation". Cropping patterns include besides "rotations", intercropping, mixed cropping, strip cropping, etc. (Pal, 1968). Kanwar (1968) defined the term 'cropping pattern' as both the time and place sequence of crops. It includes identification of most efficient crops of the region which is considered a homogenous soil and climatic belt; the rotation in which the crop fits in and the intensity of cropping.

Planning cropping patterns for feed and fodder production:

The intensive work to find out the optimum agronomical practices for the maximum utilization of acreage available for fodder production has been emphasized by Iya (1967), Ray (1967), Stone et al. (1970) and several other workers.

While giving specific recommendations, the I.C.A.R. panel of scientists (I.C.A.R., 1968) felt that there is an immediate need for intensification of research on forage crops which can give higher production per unit time per unit area so that the requirements for green forage for the cattle can be met from a smaller area than at present. Probably 7 to 10 per cent of the area in Northern region under existing cropping patterns could be devoted to the cultivation of forage crops. The intensity of cropping for the irrigated areas of this region could be raised from a minimum of 200 per cent to 300 and 400 per cent by incorporating third short duration forage crops like maize and cowpea for summer and turnips for October - November which can be fitted as catch crops between the two main grain crops. Hybrid napier
in combination with winter legumes need to be included in the cropping patterns. In Kashmir Valley, after paddy, berseem, sarson, turnip or grass seem to be suitable crops which can be fitted in double cropping. Hybrid maize is quite successful in most of the areas of Jammu and uplands of Kashmir. It can fit in the rotation with wheat, toria or potato.

Bhardwaj et al. (1968) recommended to introduce a rotation of maize + cowpea (F) — jowar (F) — potato — wheat (400 per cent crop intensity) for an assured irrigated area in Delhi while Bains and Randhawa (1970) suggested fodder rotations, maize + cowpea - sorghum - oats + berseem and bajra - maize + cowpea and berseem for this tract.

Singh et al. (1969) recommended a system of over-lapping cropping of fodder crops so dove-tailed in an integrated pattern that the yielding potentiality of different crops in different seasons is exploited for the highest forage production per unit area per unit time.

Relwani et al. (1970) suggested a relay cropping of maize + cowpea - jowar + guar - maize + cowpea - oats + pea (two cuts); maize + cowpea - jowar + guar - berseem; maize + cowpea - maize + velvet bean - jowar + guar (two cuts) - oats and mustard, for higher forage production.

Bains and Chowdhury (1970) reported that inclusion of more adapted crops in rotation as pulses, bajra and jowar (fodder) in kharif and grass, barley, lentils and linseed in rabi, is more remunerative than others. The rotation of barley - jowar - gram giving 31 q/ha of grain in addition to 186 q/ha green fodder, proved to be the most suitable because the three crops are well adapted to dry farming conditions.

Mehta et al. (1965), Singh (1970), Chakarvarty (1970), Mehta (1970) and Ghosh (1970) stated that legumes or mixtures of grasses and legumes
should be an important component of fodder planning. They recommended a number of cropping patterns consisting of high yielding grasses and various fodder crops for year round forage production in different agro-climatic regions under specific conditions of irrigations.

Work done at the N.D.R.I., Karnal, emphasized the need to plan growing of high quality fodders in intensive rotations with production potential of 150 - 200 tonnes of green or 350 - 400 q/ha dry matter giving about 35 q/ha of D.C.P. and 240 q/ha of T.D.N. A number of such crop sequences for adoption in different climatic regions of the country have been suggested (Relwani, 1970, 1971, Sundaresan, 1971, 1972).

Production Potential of Cropping Patterns:

Sequences of annual feed (G) and fodder (F) crops:

Bains and Chowdhury (1970) reported that a rotation, barley (G) jowar (F) - gram (G) yielded 31 q/ha of grain in addition to 186 q/ha of jowar fodder (green).

Sundaresan (1970) reported an average yield of 800 q/ha green fodder from a 2-forage-crop rotation, maize - berseem.

Relwani (1970) reported that he obtained 1470 q/ha of green fodder from a four-crop rotation consisting of two crops of maize + cowpea, one crop of maize + teosinte + cowpea and one crop of oats + mustard. He further gave details of other rotations like maize + cowpea - maize + cowpea + teosinte - berseem + mustard; hybrid napier interplanted with maize + cowpea in May and berseem + mustard in September; and hybrid napier and lucerne, with expected yields of 1750, 2350 and 2100 q/ha, respectively. While giving a cropping scheme for a 10-hectare specialized dairy farm to supply feed and fodder all the year round, he recommended crop rotations like maize + cowpea (F) - maize (G) - berseem + mustard (F); bajra + cowpea (F) -
maize (F) - berseem + oats (F); maize+cowpea (F) - maize (G) - pea (G);
cowpea (G) - maize (G) - mustard (F) - barley (G); cowpea (G) - maize+cowpea -
Dina grass - oats; cowpea (G) - maize (G) - pea (G) with an overall
average production potential of 1020 q/ha green fodder, 57 q/ha grains
and 142 q/ha of straw or 24.76 q/ha of D.C.P. and 236.5 q/ha T.D.N. per year.

Naidu (1971) recorded a yield of 108 q/ha grains from a 3-crop
rotation of maize - sorghum-ragi at Tamil Nadu Agricultural University.

While offering a number of multiple cropping systems Bains and
Randhawa (1970) recommended forage-crop sequences of maize+cowpea -
sorghum - oats + berseem and bajra - maize+cowpea - berseem for
incorporating in the cropping plans of farmers in Delhi Union Territory.

Swaminathan et al. (1970) reported four one-year rotations
(a) sorghum - berseem - bajra (b) sorghum - oats - maize+cowpea
(c) sorghum - berseem - maize+cowpea and (d) maize (grain) - oats -
maize+cowpea, with total dry-matter yields of 41.0, 38.7, 33.2 and
46.8 t/ha, respectively. The corresponding figures for crude protein
yields were 5.1, 4.5, 4.7 and 3.8 t/ha.

In its report on Achievements and Outlook of Agricultural Research
in India, the I.C.A.R. (1972) reported that a rotation of three crops of
maize and cowpea followed by oats and mustard produced 131 tonnes of green
fodder per hectare at the National Dairy Research Institute, Karnal.

Sundaresan (1972) reported yields of 150 t/ha of green fodder a year
from a rotation, maize+cowpea - maize+cowpea - maize+teosinte+cowpea -
oats +mustard and 200 t/ha from jowar+bajra+teosinte+cowpea - berseem +
mustard+oats.

Based upon experience gained in the Agronomy Division of the I.A.R.I.,
Bains et al. (1972) reported green fodders yields of (i) maize+cowpea -
maize + cowpea - maize + cowpea - oats + vetch, (ii) bajra - maize + cowpea - mustard - oats + vicia (iii) cowpeas - jowar - berseem + oats, and (iv) bajra + jowar + teosinte - bajra + jowar + teosinte - berseem + oats; as 1700, 1820, 2050 and 2450 q/ha, respectively.

Intercropping of perennial grass with annual legume crop:

Mehta (1965) stated that introduction of berseem in the growth rhythm of hybrid napier as an intercrop gave 800 to 1000 q/ha green fodder per year in addition to 2500 to 3000 q/ha of forage per year from hybrid napier.

Singh et al. (1969) worked out an overlapping cropping system for year round production of green fodder at the Indian Grassland and Fodder Research Institute, Jhansi, and the best crop combinations found by them with green fodder yield per hectare are: (i) berseem + japoni sarson - hybrid napier (1460 q); (ii) berseem + oats - hybrid napier + cowpea (1323 q) and (iii) berseem - hybrid napier + cowpea (1295 q).

Chakarvarty (1970) and Daulay et al. (1970) reported higher forage production of 1.86 q/ha from intercropping erwana with moth as compared to 1.26 and 1.17 q/ha, respectively, when grown singly. Similarly the yields of intercropping dhaman anjan and kard with moong, moth and guar yielded 20-30 per cent more green fodder than the crops cultivated alone.

Singh (1971) reported that the intercropping Setaria spacelata (Nandi grass) with berseem yielded 2350 q/ha green fodder per year. Patel (1970) reported a yield of 30.43 kg of crude protein from lucerne intercropped with Guinea grass while Guinea grass alone gave 19.82 kg only.

Hukkeri et al. (1971) obtained highest yield of 17.48 q/ha of green fodder cropping patterns of hybrid napier in combination with berseem followed by the combinations with berseem + lucerne (16.73 q/ha) and lucerne (15.19 q/ha).
Singh (1972) reported 20 per cent more yield of green fodder from hybrid napier followed by berseem in a rotation during winter than hybrid napier with berseem as an intercrop.

Paroda et al. (1972) indicated that the lucerne - hybrid napier rotation gave the highest yield of the order of 1670 q/ha and berseem + japan rape - sweet sudan grass gave 1580 q/ha of green fodder. Other two rotations, viz. oats - bajra - maize + cowpea and japan rape - oats - bajra + cowpea, yielded on an average 1000 q/ha green fodder.

**Nutritive value:**

The nutritive value of a feed or feed mixture can be defined as its capacity for supplying organic or inorganic nutrients which the animal can actually use for maintenance and production. To know the nutritive value it is necessary to have the data about the chemical composition which for Indian feeds and fodders grown in various regions of the country has been compiled by Sen and Ray (1964). This is necessary as the composition of the same fodder differs when grown under different soil - weather complex. For example, the calcium content of lucerne grown at Anand and Bangalore is much lower than those cultivated at Karnal and Hissar (Mudgal, 1971).

Mudgal and Des Raj (1966) reported the nutritive value of hybrid napier and recommended the stage of cutting at 40-45 days or 1.21 m to 1.34 m height to get best nutrients. Hybrid napier contains high degree of oxalic acid, but if cut and fed at proper stage, does not interfere with the mineral metabolism. Gupta et al. (1967) compared the nutritive value of hybrid napier, napier and jowar grasses with or without starch supplement and found that hybrid napier was nutritionally superior to ordinary napier and jowar. Hybridization also brought about a 50 per cent reduction in oxalic
Nutrient balance studies indicated that, of the three grasses, only hybrid napier provided a maintenance ration and the other two were deficient in proteins. Superiority of hybrid napier over ordinary napier grass was reported earlier by Singh et al. (1965).

In the earlier reports, Gupta (1966) showed that when growing calves were fed exclusively on Pusa Giant Napier grass, there was a negative calcium balance in the animals inspite of their getting the normal requirement of calcium. This was attributed to the high oxalic acid content in the grass which disturbed the calcium metabolism (Talapatra et al., 1948). Later Ranjhan et al. (1969) made an attempt to observe the balance of nutrients by conserving the green grass into hay and silage. They observed positive calcium and phosphorus balance in case of hay and silage.

The nutritive value of various feeds and fodders in terms of D.C.P. and T.D.N. have been reported by various workers at different times. The nutritive value in terms of D.C.P. and T.D.N. for Pusa Giant Napier grass as green, hay and silage was found to be 4.61, 50.64; 1.16, 52.66 and 3.16, 64.72 kg per 100 kg of oven dried fodder, respectively (Mudgal, 1971). The hybrid maize (Ganga 101) was tried as a fodder crop. The nutritive value estimated in terms of D.C.P., T.D.N. and S.E. was 6.08, 62.99 and 48.77 per cent, respectively (Sharma and Mudgal, 1968). The average yield of 113.44 q. green fodder per acre with 9.43 q. of protein per acre has been reported. The nutritive value of tetraploid Pusa Giant berseem was estimated in terms of D.C.P. and T.D.N. and S.E. - 16.66, 74.99 and 64.67 per cent, respectively on dry-matter basis, which was found to be equal to that of diploids (Sharma et al., 1968).
Role of good quality fodders:

As concentrate feeding is known to be uneconomical, research workers have been recommending their substitution by highly nutritious fodders.

Mudgal (1971) reported that a mixture of grass and legume or green maize and legume when fed at the rate of 40 kg per head per day will be sufficient for an average cow giving 5 kg milk a day, with 5 per cent butter-fat. For animals, having higher milk yield, supplemental feeding of concentrate mixture at the rate of 1 kg for every extra 2.5 kg of cow milk or 2 kg of buffalo milk has been recommended. The presence of succulent feeds, particularly green leguminous forages is expected to increase the palatability of the ration as well as to help digest more of crude fibre present in the straw.

Das Gupta (1943) reported that berseem could replace the concentrates without any ill effect on milk yield or on health of the animal. Lucerne has been reported to be as good as berseem under ad libitum feeding for milk production in cows and buffaloes (Yoelao, 1968). A partial supplementation of lucerne for concentrate has been shown to reduce feed costs with buffaloes at Anand (Patel et al., 1969). Mudgal et al. (1966) observed that the dry-matter intake increased when groundnut cake was replaced by berseem in the ration of adult bulls.

Mathur et al. (1967) could replace 85 per cent of the production ration with para grass in the diet of lactating Sindhi cows without affecting fat-corrected milk (FCM) production and composition of milk. Saran and Jackson (1967) observed no difference in yield of milk, fat, solid not-fat (SNF) and total-solids production in different treatments fed with berseem or concentrates, but protein concentration was reported to be more when only
berseem was given. Daniel et al. (1967) and Lal and Mudgal (1970) observed that protein supply for maintenance and production of milk up to 10 kg per day could be met from 50-55 kg of green berseem only.

Land requirements:

To give an impetus to dairy farming, it is necessary to convince the milk producers about its profitability over arable farming. With that end in view, various workers have been trying to assess the land requirements for meeting the maintenance and production requirements of herds of animals.

Sundaresan (1969) reported that the fodder produced from a combination of maize - berseem with 200 and 600 q/ha respectively can meet the major requirements of nutrients required by 6 cows of about 450 kg body-weight yielding 2500 litres of milk per year.

Swaminathan et al. (1970) reported that nutrients obtained from green fodders grown on a hectare of land with sorghum - berseem - bajra or sorghum - oats - maize cowpea rotation could support 10 cows each weighing 450 kg body-weight and producing 5 litres milk per day with 5 per cent butter-fat.

Keiwani et al. (1970) reported that a farmer would be able to meet maintenance and production requirements of three cows in milk and one dry, for a year from a four-crop rotation of maize cowpea - maize cowpea - maize cowpea teosinte - oats mustard, with an addition of a little bhusa in the ration on an acre of land.

Keiwani (1971) recommended the same cropping pattern for northern region and stated that 12 cows each giving 5 litres per day or 8 cows yielding 9 to 10 litres per day of milk could be maintained per hectare.

Work carried out at the National Dairy Research Institute, Karnal indicated that 20 young cross-bred cows between 3-4 years of age with an
average yield of 2500 litres of milk in a lactation of 300 days and two bullocks could be maintained on green fodder obtained from two hectares of land with a little supplementation of concentrates during peak period of lactation or when there was scarcity of legume fodders (N.D.A.I., 1971).

Work at the Indian Agricultural Research Institute, during the year 1969-70 indicated that one hectare of land could support 9 or 11 buffaloes or 12 or 14 cows with annual yield of 3000 and 2000 litres of milk respectively (Bains et al., 1972).

Sundaresan (1971, 1972), on the basis of the work done at the National Dairy Research Institute reported that 8 to 10 high-yielding dairy cows could be maintained per hectare on a farm with well planned crop rotations.

**Effect of cropping Patterns on Chemical and Physical Properties of Soil:**

**Effect on chemical properties of soil:**

Investigators have observed for many years that certain crop treatments and cropping patterns have distinct effects on the chemical properties of the soil.

1. **Organic matter content:**

   Organic matter status of a soil is considered as an index of soil fertility. Under tropical humid conditions, cultivation and cropping exhaust the soil organic matter more rapidly than they are returned, and the capacity of the soil to produce gradually declines. Various workers have shown that proper rotation including legumes maintained organic matter in the soil at an optimum level (Salter and Green, 1933; Metzger and Hide, 1938 and Greaves and Bracken, 1946). Legumes have been found to increase the organic matter status of the soil (Jones, 1942; Smith, 1950; Moore, 1962; Watson, 1963 and Rixon, 1966). This has been attributed to the profuse rooting pattern and by and large to their resistance to easy decomposition. Developed root system of legume favours the accumulation of humus in soils. This takes place even
during the growth of the plants due to the death of the root systems.

Lucerne has been found out to leave a root reserve of about 90-103 q/ha in second year of its utilization (Kanononva, 1961) in various layers. The work of Aliev (1961) showed that soils under 3-year lucerne contained 100-lii0 q/ha root residues which was 5-7 times more than cotton roots in the soil of Shir Van Steepe. Davies (1964) reported that mustard yields were highly correlated with the yields of the legume crop harvested earlier in the season, the highest residual effect being observed after lucerne followed by clovers. Dubetz and Hill (1964) compared the value of short-crop rotations containing no fodder legumes, with longer rotations containing legumes. Three 4-year, two 5-year and two 7-year rotations, including 0, 1 or 3-years of lucerne were tested under irrigation. In general there were no significant differences in yields among rotations and good husbandry practices such as applying fertilisers overshadowed any effects of lucerne in rotation on the yield. However, the organic matter and N-content of the top 15 cm of soil were maintained only in rotations containing 3 years of lucerne.

Berseem in rotation with cereal has been found to increase the nitrogen and carbon content of Indian soils (Acharya et al., 1952). The phosphate application increased the root development of berseem and resulted in the addition of about 5860 kg/ha of humus to the top soil. Increase in organic carbon content of the phosphate berseem plot was reported by Pharande (1964). Sharma and Singh (1969) did not find significant differences in the organic matter as well as in yield of maize grown after 2, 3, 4, or 5 cuts of berseem at intervals of 90, 60, 45 and 36 days. Tiwari (1964) found that non-leguminous forage such as sorghum adversely affected the yield of the following crops of wheat. He also found that if the heavy black soil is
disturbed too much by kharif crops, the yield of the succeeding crop is reduced.

No change in the carbon content of the soil due to continuous cultivation of rice was reported by Chaudhury and Vachhani (1965). Similarly no change in the organic carbon content of the soil was noticed even after five years of continuous cropping of groundnut (Nijhavan, 1962). Increase in the organic matter content of the soil was reported after a crop of jute (Annual Report, IARI, 1958-59) in a jute-rice rotation. Results of some experiments were suggestive of the fact that build-up of soil organic matter can be done by using small excess of nitrogen along with a legume programme (Bear, 1965).

Patnaik (1970) reported that compared to local varieties, high-yielding varieties remove much higher amounts of plant nutrients from the soil. Maurya and Ghosh (1972) reported that rotations have not brought about any major differences in the total P & K contents of the soil. Use of NP and NPK fertilizers indicated noticeable increase of organic matter and nitrogen in the soil.

Singh (1972) stated that minimum tillage and heavy fertilizer use followed in raising high yielding varieties in multiple cropping sequence promotes high yield and lessens the loss of organic matter.

2. Soil Phosphorus:

Sturgis (1936) reported that by continuous cultivation of rice, the available phosphorus in the soil was reduced from 12.5 ppm to 4.5 ppm. But Mandal and Pal (1965) reported an increase in the available phosphorus of the soil by continuous cultivation of jute and paddy. Singh (1965) reported that residual phosphorus after wheat increased the yield of sorghum fodder.
In a continuous cropping system a higher status of available $P_2O_5$ in soils was reported in plots receiving super-phosphate and farm yard manure (Ghosh and Kanzaria, 1964). Bucher (1951) and Hedlin and Ridley (1961) also reported similar results.

Singh (1972) reported that the soil was left richer in phosphorus contents when berseem was taken in rotation with hybrid napier as compared to the intercropping system probably due to mineralization of nutrients under the former system.

Mehta and Raman (1972) reported that the amount of $P$ removed from the soil was maximum ($168$ kg $P_2O_5$/ha) in hybrid bajra - lucerne rotation followed by a 4-crop rotation of soyabean - jowar - wheat - bajra ($1400$ kg $P_2O_5$/ha).

On the basis of the trials with various rotations they recommended that high amounts of phosphatic fertilizers are required in relay cropping.

3. **Soil potassium:**

Continuous cultivation of rice was reported to reduce the exchangeable potassium of the soil (Sturgis, 1936). But other investigators have not observed any change in the potassium status of the soil due to various cropping systems. Blair and Prince (1936) and Hofmann et al. (1950) did not observe any increase in soil potassium by cultivation of various crops with the addition of potash fertilizers. Similarly Ghosh and Kanzaria (1964) reported that there was no change in total $K_2O$ in soil by continuous cultivation with the addition of potassic fertilizers.

Ozaki (196u) reported that whereas phosphorus, magnesium and calcium seemed to have been retained in the soil in all cropping systems, nitrogen and potash significantly decreased where test crops were combined with soyabean, barley, wheat or oats but not with maize, potato or sugarbeet.
Mehta and Raman (1972) found that when bajra was included in rotation, it had a profound effect on K removal. The removal of K from the rotations of mung-bajra-wheat-bajra, mung-bajra-wheat-vegetable crops, and hybrid bajra-lucerne, was of high order at 462, 365 and 418 kg K2O/ha, respectively. They concluded that with high-yielding varieties and relay cropping the amount released may not be commensurate with amounts removed by crops and hence it would be necessary to add potassic fertilizer in such intensive cropping.

1. **Effect of Cropping Systems on Soil Structure:**

The influence of cropping system on soil structure is a reflection of combined effect of physical, biological and chemical agencies (Harris et al., 1966). The relative contribution of these agencies in the formation and degradation of soil structure varies with different cropping systems. The maintenance of optimum soil tilth can be accompanied by judicious choice of cropping patterns.

A comparison of management system showed that Dunmore silty loam under grass for 30 years was better aggregated than soils that are cropped continuous with corn or wheat (Elson, 1940, 1943).

In a study of various cropping systems at Iowa, Johnston et al. (1942) showed that the size distribution of soil aggregates had been materially influenced by the cropping systems with the greatest number of large sized aggregates in the descending order, blue grass, clover, oats rotation, corn rotation and continuous corn. Red clover in rotation maintained a loose granular structure whereas continuous corn made the soil cloddy and difficult to work.

From a study of soil aggregation, run off and erosion as affected by cropping systems Silson and Browning (1945) concluded that the percentage of
water stable aggregates greater than 0.25 mm for different crops were in the order of continuous blue grass, continuous alfalfa, rotation clover, rotation oats, rotation corn and continuous corn. In the later studies Wilson et al. (197?), and Gish and Browning (1948) found that aggregate status as affected by cropping systems was in the following descending order: continuous blue grass, rotation meadow, rotation corn and continuous corn. Olmstead (1946) in a comparative study at Kačas showed that the soils under different cropping systems of continuous small grain and continuous row crops lost approximately 80 per cent of their initial aggregation in the surface tilled zone, since they were broken from grass land.

The effects of 3 cropping systems on crop yield, soil aggregation, soil organic matter content on Beltsville loam were studied by Strickling (1957). He found significant differences in soil organic matter content and soil aggregation. Continuous wheat, blue grass, grass pasture increased soil aggregation. On the other hand, continuous soybeans and bare fallow reduced soil aggregation and organic matter. Changes in organic matter were accompanied by changes in aggregation.

Bolton and Webber (1952) reported that the aggregation at 0-4 inches depth was markedly increased by cropping systems in the order of blue grass, lucerne-brome grass (one year), lucerne-brome grass (2 years) and continuous maize.

Jones (1961) examined silty loams and reported that increase in intertilled row crops in rotation decreased aggregation. Continuous cropping of maize and soybeans over a long period changed the soil structure from granular to massive structure. Aggregation and porosity were positively correlated with organic carbon.
Malik et al. (1965) compared the effect of four cropping systems on water stable aggregation. Water stable aggregation in grass land was found to be significantly higher than the other three long term systems, namely, corn in nine years, continuous wheat and four years of alfalfa.

Prabhakara (1970) reported that relay cropping not only maximised crop yields per hectare per day, but also kept up the physical properties continuously under optimum conditions throughout the year.

2. Effect of Crop Rotations on Soil Structure:

Alderfer and Merkle (1941) found that the intensity of soil under a corn-oat-wheat-clover rotation showed deterioration in physical condition as compared with the soils under grass. Soils under continuous cultivation were in less favourable structural conditions than the areas under rotation. The stability of aggregates were found to be positively correlated with organic matter. The bulk density values showed inverse relationship to aggregate stability and organic matter content.

With a four year rotation of corn, wheat, clover and grass, Elson (1943) found that soil under wheat had same percentage of aggregates (greater than 1.0 mm) as that under corn. Soil under clover showed 10.3 per cent increase in aggregation over wheat. Areas under the grass treatment brought about 9.1 per cent increase over clover.

Strickling (1950, 1957) studied soil aggregation for a period of years in a rotation experiment on silty loam. Soil aggregation showed definite seasonal trend under all crops and aggregation was much lower in maize-soyabean than maize-wheat rotation. Soyabean and maize had same effect on aggregate stability.
Vandoren et al. (1952) showed that the soil samples from plots under corn-corn-soyabean rotation were dense and compact and had a percolation rate 0.2 inches/hour. Soil samples from plots with a rotation corn-corn-clover-clover were porous and had good tilth. The percolation through the core samples from this rotation was 3.2 inches/hour.

Deshpande et al. (1953) reported that no significant differences in the degree of aggregation, volume weight, total pore space and percolation were observed in soil under continuous cotton and cotton-jowar or cotton-jowar-groundnut in rotation.

Dakshinarauy (1966) reported that when green matter of jowar or maize plants obtained from a jowar-wheat or maize-wheat rotation were incorporated into soil by ploughing in, a significant improvement of soil structure was observed. Apratt (1966) showed that the soil samples from the rotation, brome-alfalfa had higher content of organic matter and good physical condition than the samples from sunhemp-fallow-wheat-wheat rotation.

Padma Raju (1967) found that to preserve structure of soil under rice in intensive cultivation it is desirable to include leguminous crops like pea, berseem in rotation but not potato.

Singh (1971) found significantly higher bulk density, better soil aggregation and higher organic carbon content in intercropping system as compared to a rotation cropped with hybrid napier-berseem.

Singh (1972) reported that the micro-organism affecting the decay of plant residues and the intermediate organic substances they produce, markedly increase soil aggregation. He also reported that heavy fertilizer use followed in raising high yielding varieties in multiple cropping sequence promoted high yield, lessened loss of soil organic matter and large amount of
decomposable stubbles and root residues were added which were essential for good tilth and good soil physical condition.

3. Effect of Grasses on Soil Structure:

The massive root systems, continuous supply of residues and effective protective coverage provided by grass afford optimum condition for establishment of good soil structure (Harris, 1966). The most feasible way of maintaining soil structure is by combining arable agriculture with grassland farming. This may be described as a sort of compromise with nature in which we will cultivate the soil for few years and produce food crops and then turn soil back to nature for recovery.

Many workers have known that grass has marked effect in increasing aggregation of the soil. On the other hand, soil structure tends to deteriorate under row crops as a result of intensive cultivation. Henry and Newwell (1947) observed that organic matter content and favourable physical condition were maintained relatively high under perennial grass than the adjoining cultivated lands. The beneficial effect of perennial herbage in improving soil structure was also reported by Petroshinke (1949). Low (1950) states that the only method of restoring physical condition of old arable soil is to cultivate grass.

Mandal (1956) classified the crops into two types, namely, soil depleting crops (maize, cotton) and soil conserving crops (lucerne, bermseem, grasses). He found that perennial grass improved water stable aggregation. Wehrli (1958), from an investigation on the effect of grass and legume on soil structure concluded that the beneficial effect of grass on soil structure was apparent within five months of its establishment, thus showing the establishing effect of grass in the mixture. Barber (1959) found that the percentage of water stable aggregates was highest after brome grass
and lowest after corn. A mixture of alfalfa and brome grass gave an aggregation index between that of alfalfa and brome grass.

Williams and Cook (1961) found that continuous grass was more effective than annual dressing of farm yard manure in making soils permeable and in making aggregates stable to water.

Williams (1963) stated that there was an increase in aggregate stability of a sandy loam caused by one, two or three years under grass and that there was a slightly degradation of structure after ploughing grass—land, on a clay soil.

4. Effect of Legumes on Soil Structure

Legumes have been one of the mainstays of good rotation for many years. In many instances beneficial effects of legumes occur through the fixation of nitrogen by nitrogen fixing bacteria like Rhizobium and thus maintaining adequate reserve of nitrogen. In addition, legumes have helped to maintain good soil tilth, firstly through the contribution of organic matter by the roots and secondly through the increased production of organic matter in the non-legume crop following it (Tisdale and Nelson, 1966).

Hide (1939) found that legumes, produce more large sized aggregates than in the land left fallow. Johnston et al. (1942) observed that clover in rotation maintained a loose granular structure whereas continuous corn left the soil cloddy and difficult to work. They demonstrated the importance of good vegetative cover with legumes in rotation for maintenance of favourable structural condition, organic matter content and reduction of soil and water losses. Uhland (1949) reported that deep rooted legumes like Kudzu and alfalfa increased percolation rate of entire profile. The volume of pores drained was several times greater for land growing alfalfa and Kundzu than land cropped annually to cotton. Nehar (1950) stated that
Lucerne appeared to increase the percentage of water stable aggregates, its residual effect lasting as long as eight years.

Acharya (1954) found that berseem added higher contents of organic matter and nitrogen than lucerne. Fringelle, et al. (1956) observed a marked increase in aggregation under clover and slightly less under grass-clover mixture, in their first year of study. Gupta and Jen (1962) observed that highest aggregation of soil was caused by Rhizobium sp. of pea crop.

Prabhakara (1970) indicated that the physical properties were the best after legume crop in relay cropping.

5. Effect of Grass-Legume Mixture on Soil Structure:

In certain respects, advantages of leguminous root systems complement those of grass roots. Although leguminous plants do not provide a large volume of fine roots like grasses, their roots contain more nitrogen and decompose more rapidly than grass. Roots of grasses and legumes improved aggregation of soil by (i) aggregate formation around roots involving the adherence of fine soil particles to living root hairs; (ii) bacteria and fungal hyphae (Mishustin, 1945; Hubbel and Chapman, 1946) excretion products which act as soil binding agents (Egawa and Sekiya, 1956) and, (iii) gums and mucus produce added in the soils. Uhland (1959) found legumes mixed with grasses formed higher percentage of water stable aggregates than legumes alone. Jablonski (1957) indicated that grass-legume mixtures had a better effect on aggregate formation than pure stands of legumes. Soil structure after was better after perennial legumes mixed with grasses than annual legume.

Birecki et al. (1961) found that aggregates 3 mm formed under clover-grass mixture were more than under lucerne alone, and that more aggregates 3 mm were formed under a pure stand of lucerne. Structure
formation was better under perennial plants than under wheat or fallow.

Singh (1971) reported that the plots where berseem was grown as an intercrop with hybrid napier had significantly higher bulk density, better soil aggregation and higher organic matter.

**Economics and Labour Employment:**

The most important factor in the adoption of any cropping pattern by the farmer is its profitableness. Some cropping patterns need more investment of labour. Hence, depending on the availability of capital and labour, the farmer adopts such cropping patterns that will give him the maximum returns.

**Economics of cropping patterns:**

Due to paucity of information on economics of cropping patterns involving feeds and fodder crops, such rotations as deal with cereal and cash crops have been included in the review to get an idea of relative returns from the feeds and fodders in comparison to these crops. It would have been desirable to consider the economics at constant prices so that the periodical changes in cost of production and sale prices do not affect the results but it is not possible for want of adequate data. The returns from various patterns are, therefore, not be taken at their face value but only as an indication of the trends.

The economics of various cropping patterns adopted by farmers of Cuttack district, Orrisa State, were reported by Mahapatra (1967). He found that by following the crop rotation groundnut-jute-rice, the farmers got a net profit of Rs. 2,100/- per hectare per year. This was much higher than the income from the usual cropping patterns practised by farmers.
Bains et al. (1968) found that by relay cropping of 400 per cent intensity the farmers can get a profit of about Rs. 11,500/- per hectare per year. They studied the economics of two cropping patterns, viz. (1) moong-maize-toria-wheat and (2) moong-maize-potato-wheat. From the first cropping relay sequence, they found a net profit of about Rs. 10,000/- per hectare, whereas from the second cropping relay sequence they got a net profit of about Rs. 11,500/-.

Increase in the annual returns to the extent of Rs. 1,500/- per hectare was noticed by multiple cropping of jute fields (Pandey et al., 1968). The cropping pattern adopted was jute in rotation with paddy, berseem and potato.

Pandey and Goswami (1968) reported a net profit of Rs. 4,936/- per hectare by multiple cropping of jute and potato, whereas from jute and wheat a profit of Rs. 3,430/- per hectare was obtained.

Mahapatra (1969) reported that cultivators in Cuttack District, Orrisa State obtained a net profit ranging from Rs. 2,860/- to Rs. 5,700/- per hectare by adopting the cropping pattern rice-potato-rice.

The maximum annual profit of Rs. 5,300/- per hectare was obtained from the cropping pattern jute-rice-wheat at Barrackpore, West Bengal (Pandey et al., 1969). By following the cropping pattern jute-rice at C.R.R.I., Cuttack, the net profit obtained was Rs. 3,380/- per hectare.

Arora and Pandey (1969) reported a gross return of Rs. 14,320/- per hectare per year by following the cropping pattern potato-wheat-jowar. When the cropping pattern was radish-wheat-jowar, the gross return was only Rs. 12,900/-. Thus inclusion of potato crop in the cropping pattern yielded the maximum gross returns.
Singh (1970) reported that detailed investigations on the economics of various cropping patterns were in progress at the U.P. Agricultural University. He, however, gave the net returns of the following cropping patterns (a) maize - potato - potato, (b) maize - potato - tobacco and (c) maize - potato - pumpkin, as Rs 4770, Rs 3800 and Rs 4000 per hectare at farmers' fields in Farrukhabad.

While studying and demonstrating economics of different types of farming, from 1962 to 1963, the workers at the National Dairy Research Institute, Karnal (final report, N.D.R.I., 1968) observed that production of hybrid napier by intercropping with berseem and cowpea was more economical.

Bains and Randhawa (1970) while reporting the cost-benefit analysis of a four food-crop rotation: mung - maize - potato - wheat, indicated that this system calls for an investment of about Rs 4220 and yields a net profit of Rs 11,580 per hectare. They also recommended an economic rotation of three fodder crops of maize+cowpea - sorghum - oats + berseem for Delhi territory.

In Himachal Pradesh, three rotations, mung - maize - potato - wheat, maize - potato - wheat and mung - maize - toria - wheat gave maximum net returns of Rs 8850, Rs 7950 and Rs 6170 per hectare, respectively (Jogi et al., 1970).

Sahu (1970) reported that by changing the cropping pattern and adopting multiple cropping, a farmer increases his production by 2½ times per unit area per unit time and gets a net income of Rs 4100 with an additional investment of Rs 2025 per hectare. In upland conditions with a 3-crop system the production increases by 311 per cent and net income by 224 per cent over a single conventional crop and cropping system. The corresponding figures for the medium land are 125 and 116 per cent and the low land conditions 35 and 118 per cent.
Singh (1971) found the sequential cropping system of cultivating hybrid napier and berseem most remunerative with a net profit at Rs 5940 per hectare per year.

Tripathi et al. (1971) found that farmers of North Bengal could realize an extra net income of Rs 2730 per hectare by adopting triple-cropping pattern of aus paddy-aman paddy-Motihari tobacco over double-cropping pattern of growing aus paddy or jute followed by Motihari tobacco which is the customary practice now.

On the basis of the results obtained from the National Demonstrations, Misra (1971) stated that two-crop rotation of bajra and wheat could earn a net profit of Rs 2410 to Rs 4130 per hectare in the North Western region.

Venkataraman (1972) reported that the multiple cropping pattern consisting of grain crop of paddy in kharif followed by a cash crop of groundnut and wild indigo as a summer green manure crop in fallow land is expected to bring net income of Rs 6250 per hectare in one year as against present income of Rs 1500 per year obtained with a single crop of paddy.

Mitra et al. (1972) stated that the rotation which included mung intercropped with jute, followed by paddy and thereafter by potato gave largest profit of over Rs 10,000 per hectare per year.

Sadananan and Mahapatra (1972) reported a net profit per hectare of Rs 8760 from potato-rice-rice, Rs 5990 from maize-rice-rice, Rs 5400 from groundnut-jute-rice and Rs 7060 from rice-jute-rice.

Singh and Patel (1972) reported that highest average return per hectare of Rs 7335 was realized from the three-crop rotation of paddy-wheat-bhindi, followed by rotations of paddy-wheat-mung and paddy-wheat-jowar (fodder) which netted an income of Rs 5600 and Rs 5030 per hectare, respectively.
The results of the cost benefit analysis of different crop sequences studied at the Indian Agricultural Research Institute from 1967-68 to 1970-71 Bains et al. (1972) observed that the cost of production increases with an increase in the intensity of cropping. Considering the net profits per annum from different crop sequences it was found that quadruple cropping mung-maize-potato-wheat proved to be the most profitable giving as high income as Rs. 10,960/- per hectare followed by the sequences like mung-maize-radish-wheat (Rs. 8,450/-), maize (cobs)-bajra (fodder)-wheat (Rs. 7,130/-) and mung-maize-wheat (Rs. 6,390/-). Similarly 4-fodder-crops-sequences of bajra-turnip-oat-maize-cowpea gave net returns of Rs. 6,080/- per hectare as compared to 3 fodder crops of maize-cowpea-berseem-bajra (Rs. 5,590/-) and sorghum-berseem-bajra (Rs. 5,300/-). The relative position of different crop-sequences, however, changes when their profitability per rupee investment is considered. The economic analysis of multiple crop sequences brings out the fact that scientific multiple cropping has a high income potential per unit area per unit time.

Mathur (1972) reported a net return of Rs. 10,340/- per hectare from a cropping sequence of four crops in a year (bajra - potato - wheat - maize). Amongst the 3-crop rotations tried under National Demonstrations, rice - wheat - mung, gave net return of Rs. 8,690/- per hectare per year.

Economics of milk production:

Now-a-days, as many milk supply schemes are coming up and the producers are assured of fair price and marketing facilities, organised dairy farms are gaining impetus. The study of cost of milk production and economics of dairy farming in organised farms under multiple cropping of
feed and fodder crops is, therefore, very essential in order to devise ways and means to maximise profit.

In India, not many studies have been made in this direction, except at Aarey Milk Colony, Bombay, during 1950-51, (Salpekar, 1958) and in the military dairy farms during 1952-53. Of late many attempts have been made to study the cost of production of milk in rural areas. Anand Agricultural Institute (Madiman and Desai, 1951), Jamia Institute of Agricultural Economics and Rural Society (1952-53) and the Board of Economic Enquiry, Punjab (1953-54), are among the agencies who conducted enquiries on a small scale. Indian Council of Agricultural Research made extensive studies in this direction since 1953 in urban and rural areas of Delhi (Panse et al., 1961), Madras (Panse et al., 1963) and Calcutta (Panse et al., 1965).

Panse et al. (1961, 1963 and 1965) reported that the feed accounted for about 67 per cent of the gross cost in urban areas, 55 to 57 per cent in the sub-urban areas and about 62 per cent in rural areas. The average cost per litre of cow milk as well as buffaloe milk was low in large smaller stables. This trend was also observed for feed, labour and depreciation on animals. They also indicated that the cost of production of milk was least in winter season and increased successively in the summer and rainy seasons.

Ram and Singh (1972) reported that feed accounted for 2/3rd. Of the gross cost of milk production in the studies made at the N.D.R.I., Karnal, for the year 1961-62, 1966-67, 1969-70 and 1970-71 and Bangalore 1963-64. The concentrates made up 58 to 61 per cent of the total feed cost. Based on these findings, the amount of concentrate was reduced and corresponding nutrients adjusted by increasing the quality of green fodder.

The workers at the Economics Division of the National Dairy Research Institute, Karnal, have found that there is a relationship between the level
of milk production and the cost of milk production. As the yield goes up the cost of milk production comes down. (Rastogi et al., 1971; Sundaresan, 1972).

**Economy through green feeding:**

Das Gupta (1963) reported that the feed costs for milk production and for growing stock could be reduced substantially by replacing proportion of the concentrates in the traditional dry roughage concentrate ration by berseem.

At the National Dairy Research Institute, considerable economy in feeding has been achieved by giving leguminous fodders to cows. In the rabi season when plenty of berseem and lucerne were available, the amount of concentrate mixture was cut down at the rate of 1 kg per cow (Mudgal and Ray, 1964).

Puri and Singh (1964), Mathur et al. (1967), Saran and Jackson (1967), Jackson (1968), Daniel et al. (1970), Patel (1970), Ahuja (1970) and Mudgal and (1971) reported that the cost of livestock raising, milk production can be substantially reduced by feeding green fodders and reducing the concentrates.

Relwani (1970) reported that by feeding about 35 kg of green and nutritious fodder per day per cow and supplementing it with about 3.0 kg of wheat bhoosa, 14-15 cows each giving 5.0 litres of milk can be maintained per hectare.

Patel (1970) reported that daily cost of feeding a growing heifer of 600 lb body-weight comes to Rs 4.50 on roughage and concentrate ration whereas on all roughages ration it comes to Rs 3.00 only. Similarly, for a cow yielding 50 lb milk per day the cost comes to Rs 9.10 and Rs 7.00, respectively.
Sundaresan (1971) reported that high quality fodders like berseem and lucerne produce a kilo of digestible crude protein at the rate of Rs 1.20 only while it will cost Rs 2.50 if fed through concentrates.

Patel (1971) reported that by feeding 10 kg of green lucerne fodder to a milch buffalo per day, 700 g of milk yield is increased per day and there can be saving of 1 kg concentrates per day per animal.

Mehta (1971) reported that oats and bermuda grass fodder when fed at the rate of about 40 kg and 32 kg per day, respectively, can eliminate concentrates from the ration of a cow producing 10 kg of milk per day.

Shukla (1972) reported that feeding a buffalo with green fodder costs Rs 3.02 only per day whereas feeding with dry fodder with concentrate costs Rs 4.24 per day. It is, therefore, advisable that farmers should feed their animals with green fodder and thereby reduce cost and increase profit in milk business.

Economic returns of dairy enterprise:

Sundaresan (1970) reported that the returns in dairying using highly productive dairy cattle will be more remunerative than cultivation of grain crops of wheat-maize. High milk yielding buffaloes found in Punjab can provide a return for land, capital and management invested of about Rs 3,000/- per hectare a year, which is comparable to the returns obtained from a hectare of land put to the maize-wheat combination, today, under high productive technology.

Relwani (1970) stated that with cows yielding 6, 8 and 10 litres of milk per day a hectare of land under fodder crops could provide incomes of Rs 6,640/-, Rs 9,720/- and Rs 12,790/-, respectively.
Nair (1970) and Dabas et al. (1971) reported that dairy farming yields higher average net return per hectare than the arable farming. Raut and Chugh (1971) stated that the per capita income of a farmer who would resort to either dairying or mixed farming would be much higher as compared to present per capita income on arable farming. The work carried out at the National Dairy Research Institute indicated a minimum net return of Rs 6,000/- per hectare under intensive dairy farming system (Sundaresan, 1971; NDRI, 1971).

Bains et al. (1972) reported an additional net incomes per hectare of Rs 2,750/- to Rs 6,810/- from a group of milch buffaloes each yielding on an average 3,000 litres of milk per annum and Rs 1,210/- to Rs 5,490/- from cows with the same production potential maintained at four different cropping patterns over crop enterprise.

Labour employment:

The labour force employed in agriculture varies from country to country depending upon the degree of industrialization, productivity of labour and the level of economic development in the country. Swaminathan et al. (1970) reported that 69 per cent of our human population is engaged in agriculture in India while the corresponding figures for U.K. - 5%, U.S.A. - 12%, Japan - 50%, West Germany - 22%, France - 27% and U.S.S.R. - 42% only (U.N., 1961).

Rao (1971) and Morse (1971) have opined that there is a large number of people in India (above 30 million in agriculture alone) who are unemployed. Many more are under-employed and still more who are employed on wages and earning below the subsistence level. And this number has been rising at the rate of some seven million persons a year roughly.
According to the report on Intensive Agriculture by the Agricultural Labour Enquiry for 1950-51 and 1955-56, in the year 1950-51, about 13 per cent agricultural workers were without wage employment even in the peak labour-work-load period in agriculture. Agricultural men workers got employment for 139 and 194 days on wages in agricultural employment and for 29 and 28 days in non-agricultural employment and were totally unemployed for 82 and 110 days in 1950-51 and 1956-57, respectively.

Tandon and Dhondhyal (1971) calculated labour months utilization of the farmer and his family in cultivating two crops a year and looking after a pair of bullocks and two cows at 2.4 hectare farm as 6.75 months a year. For the rest of the year, the family remains mostly without work. On a vast majority of the small-scale family farms, the unproductive unemployed persons have to be fed from the total agricultural out-put of the family, thereby, reducing the profit margin in agriculture. It is estimated that agriculture creates about 10 times as many jobs as does industry per unit of investment. Agriculture has to continue to provide additional employment to about 4 million persons a year over and above the existing un- and under employed of whom there are about 40 to 50 million right now (Chowdhury, 1972).

**Labour in crop enterprise:**

Johnson (1968) and Kanwar (1970) reported that multiple cropping is an effective tool in the hands of Indian agriculture to absorb the surplus manpower which will be looking for employment.

Heady and Aggarwal (1970) found that for the next two decades multiple cropping promises to be a more effective means of creating employment for the growing and already large population in rural areas than does that prospect of industry.
Swaminathan et al. (1970) reported that if only 10 million hectares of irrigated land is brought under 3 to 4 crops-a-year sequence in a phased programme during the 4th five year plan period, this could absorb as much 15-20 million extra persons which seems to be the estimate of fully unemployed workers in the rural areas.

Tandon and Dhendyal (1971) stated that the full use of labour throughout the year can be made either by expanding the farm business through intensive farming or by adding supplementary enterprises. Under the intensive cropping programme, the human labour utilization is worked about 9.5 months a year. Inclusion of supplementary enterprises is more profitable as they provide an opportunity to a farmer to increase his income without adding to labour costs.

Bains et al. (1972) analysed the relative employment potential of different crop sequences and reported that by four crops a year (mung-maize-potato-wheat) there was an increase of 80-140 per cent in the employment potential over 2-crops a year.

Chowdhury (1972) reported that a fodder crop sequence of maize+cowpea-sorghum-berseem provides full time employment for an adult man per hectare in the process of raising crops only. He estimated that 16-17 million persons could be found new jobs in crop production alone if the programme of multiple cropping is implemented and executed to its logical conclusion.

Sirohi et al. (1972) reported 400 per cent increase in labour employment by introducing multiple cropping with credit facilities to the farmers and without credit facility, only 100 per cent increase was observed.

Labour in dairy enterprise:

Sundaresan (1970), Swaminathan et al. (1970) and Bains et al. (1972) reported their estimates of labour requirement on the basis that two men would
be required to look after the management of about 10 dairy cows in addition to the ones required for raising of feed and fodder crops.

The work done at the National Dairy Research Institute, (NDRI, 1971) indicated that for management of 20 cows and two bullocks, on an average four daily paid labourers shall be engaged for cleaning the cattle sheds, cultivating land, harvesting fodder, chaffing and feeding fodder.

Raut and Chugh (1971) reported that the extent of labour utilization per year both for farm and stall operation was 1086 man-days per hectare in dairy enterprise.

Chowdhury (1972) found that with dairy enterprise, a total employment of 1095 men-days per hectare or 3 men per hectare per year are required.