RESEARCH REVIEW JOURNALS
Volume-03
Issue-06
June-2018

ISSN: 2455-3085 (Online)
RESEARCH REVIEW International Journal of Multidisciplinary
www.rrjournals.com [UGC Listed Journal]

Evaluation of Agricultural Productivity using Remote Sensing and GIS in Dindigul Panchayat Union, Dindigul District, Tamil Nadu

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ARTICLE DETAILS

Article History
Published Online: 12 June 2018

Keywords
Agricultural productivity, METLAND Model, Soil suitability, Land use detractor rating, Normalized resource value rating

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ABSTRACT

Agriculture is still the main source of income for India including Tamil Nadu. There is an alarming need to increase food production to meet the need of increasing population. In order to fulfill this, the agricultural productivity of our land resources should be maintained to achieve the optimum utilization of land. The term “Agricultural Productivity” can be defined as a measure of efficiency in an agricultural production system which employs land, labour, capital and other related resources. For this, an attempt is made to evaluate the agricultural productivity of Dindigul panchayat union for the years 1973, 1997 and 2017.

Metropolitan Landscape Planning Model (METLAND Model) aims at identifying the levels of agricultural productivity since it evaluates a direct relationship between soil, land use and agricultural productivity. This model analyses the interaction between the Soil Suitability and Land use Detractor Groupings. According to the suitability for traditional crops, soil suitability map is prepared and land use maps are derived from the appropriate satellite images. By aggregating the soil suitability and Land use detractor groups, the agricultural productivity is evaluated for the study area. This analysis would help the planning authorities for future development.

1. Introduction

Agricultural productivity is a reliable index to understand the agricultural efficiency of a region. Productivity is the concept that describes the relationship between the output and the major input like, land, labour and capital. Agricultural productivity is a function of several variables pertaining to physical, socio-economic, technical and organizational aspects. Evaluating the agricultural productivity of an area using remote sensing and geographic information system may be much more useful to plan for a better cropping pattern and thereby improving the productivity of an area. Hence in the present study, it is proposed to evaluate the agricultural productivity of Dindigul panchayat union in Dindigul district using Remote Sensing and Geographic Information System.

2. Study Area

Dindigul Panchayat Union is located in Dindigul district, Tamil Nadu (Fig1). The study area lies between 10°14’45” and 10°31’00” North latitudes and 77°45’ and 78°4’30” East longitudes covering the Survey of India (SOI) topographic map 58 F/14, F/15, F/16 and 58 J/3 extending over an area of 378.71 Sq.Kms. The area consists of 18 administrative units i.e., village panchayats namely Adiyanuthu, Agaram, Alakkuvarpatti, Ammakulathupatti, Anaipatti, Balakrishnapuram, Chettinaickanpatti, Kovilur, Kurumbapatti, Mullipadi, Pallapatti, Periyakottai, Silapadi, Sirumalai, Thadikombu, Thamaraipadi, Thottanuthu and Vellodu. Among these, Sirumalai village panchayat is a hilly area located in the southern part of the study area. Dindigul (C)(Corporation) is the headquarters of the study area (Fig 2).

Fig 1 Study Area - Location Map

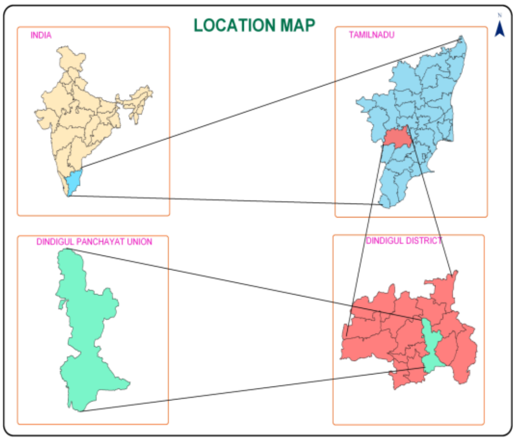
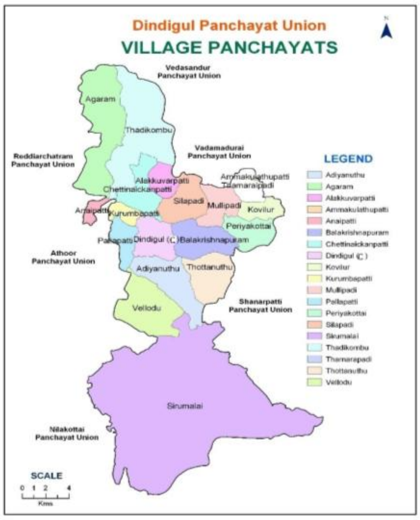


Fig 2 Dindigul Panchayat Union - Village Panchayats

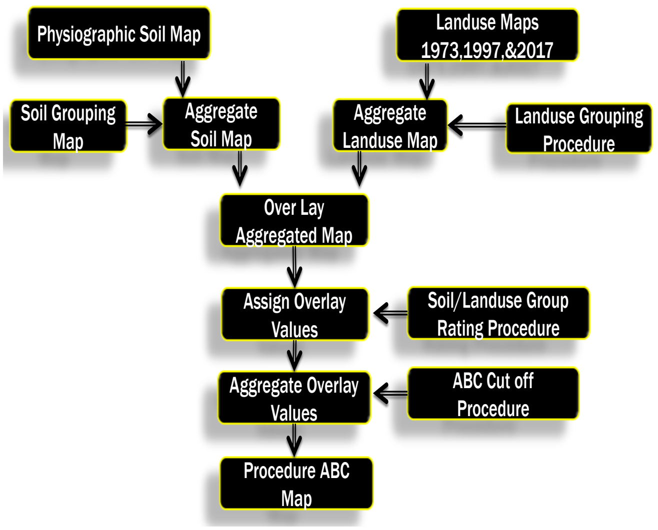


3. Methodology and Data Base

In 1971, the Metropolitan Landscape Planning Model (METLAND) was devised, which was used to preserve the environmental resources and formulate plans for regional development. The assessment technique for agricultural productivity developed by the METLAND team of Massachusetts University, USA, (METLAND Research Report, Williston, 1973 and METLAND Research Report, Stephanie J. Caswell, 1975) utilizes the SCS (Soil Conservation Service) classification of soil types for agriculture. The METLAND team observed a direct relationship existing between soil, land use types and agricultural productivity.

As the Metropolitan Landscape Planning Model (METLAND Model) (Flow Chart 1) concentrates more towards urban environment, as a site of specific case, this model is applied in Dindigul panchayat union. Further the METLAND model aims at identifying levels of agricultural productivity with the objective of formulating plans for regional planning (Julius Gy. Fabos and Stephanie J. Caswell (1977).

Flow Chart 1 Methodology for Evaluating Agricultural Productivity - Metland Model



The actual step-by-step design of this METLAND agricultural assessment technique is as follows.

Step1: Aggregate Soil types into Soil Suitability groups and assign a Suitability Rating to each group

This aggregation is based on the Soil Conservation Service (SCS) soil classification system which groups soil types into capability classes according to their relative suitability for traditional crops (Mott John, R and Donald C. Fuller, 1967).

Step 2: Aggregate land use types into Land use Detractor Groups and assign Detractor Rating to each group

This aggregation is based upon the estimated similarity of land use types in terms of:

1) the degree to which they modify the natural productivity of the soil for agriculture and
2) the likelihood of their reverting or the effort required to revert them to agricultural use.

Similar land use types form a single land use detractor group. A total of 8 land use detractor groups is generated in this way. Assigned detractor ratings express on a 0-100 scale [ie., minimum-maximum detraction] the relative difference among land use detractor groups (METLAND Research Bulletin No: 602: Julius Gy. Fabos, 1973).

Step 3: Determine the Resource Value Ratings normalized to a 0-100 scale which result from the interaction of Soil Suitability Groups and Land use Detractor Groups

The following formula is used for this determination (Julius Gy. Fabos and Stephanie J. Caswell. 1977).

$$X = \frac{[(s - t) + 75] * 100}{175}$$

Where, s = the soil suitability rating, t = the land use detractor rating and X=resource value rating in 0-100 scale which results from the interaction of the two.

The purpose of this formula is to generate the agricultural resource values that result from considering the natural suitability of soils in concern with the detraction provided by existing land uses. Logically, the resource value “X” of any parcel of land is seen to equal its soil suitability rating “s” minus its land use detractor rating “t”. The remaining elements in the above equation serve to normalize the resource value obtained by this subtraction according to a 0-100 rating scale which is used by METLAND simply to standardize the assessment results generated by all its developed variable assessment techniques.

Step 4: Aggregate Normalized 0-100 Resource Value Ratings into A-B-C Classes

This aggregation serves to categorize 0-100 ratings in terms of 3 levels of relative potential resource value. These are high agricultural productivity, moderate agricultural productivity and low agricultural productivity zones (Julius Gy. Fabos and Stephanie J. Caswell. 1977).

The physiographic soil map of the study area is prepared from imagery. The interpreted soil map was verified through field check and related verifications. The land use maps of the study area are prepared by interpreting Land sat 1 (1973), Land sat 5 (1997) and land sat 8 (2017).

4. Objectives

To evaluate the agricultural productivity in the study area for 1973, 1997 and 2017.

5. Results and Discussion

Aggregate Soil Map Ratings

The physiographic soil map with its soil family classes is shown in Figure 3.

Fig 3 Dindigul Panchayat Union – Physiographic Soil

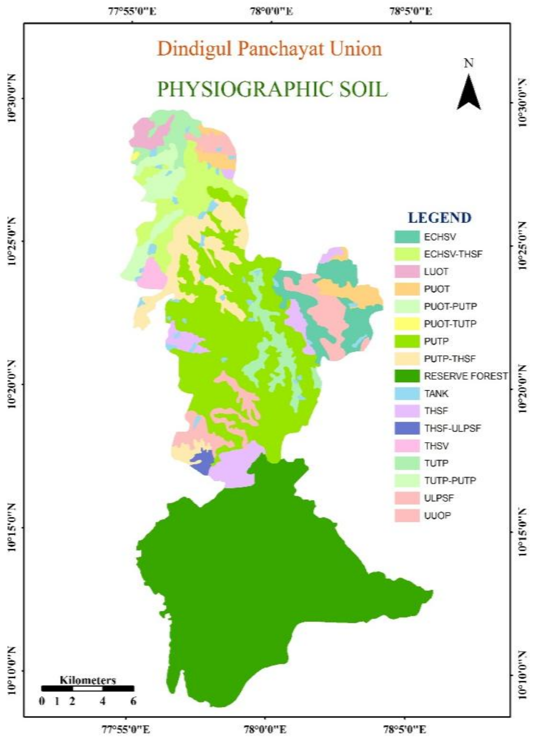
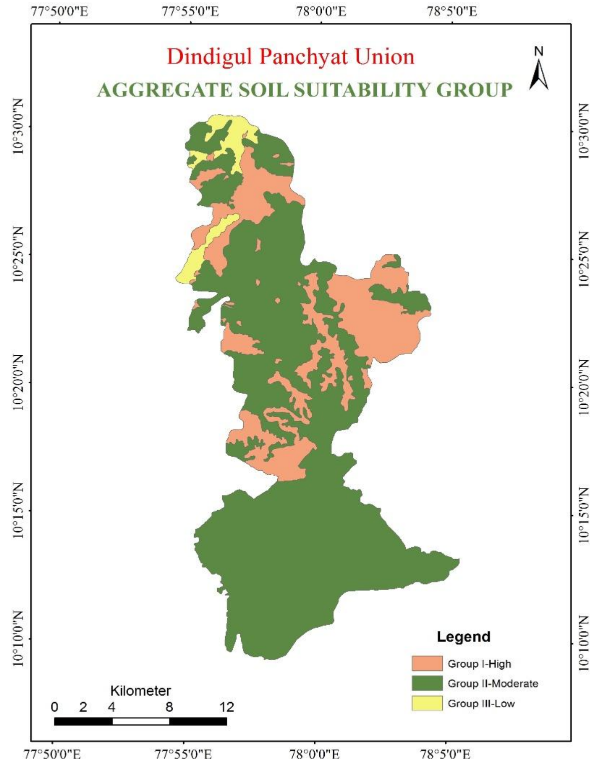


Fig 4 Dindigul Panchayat Union–Aggregate Soil Suitability Group



The soil families of the study area, their suitability for agriculture and their relative ratings for agriculture in 0-100 linear scale is given in Table 1. This aggregation is based on the soil classification and their suitability for traditional crops.

Table 1 Soil Suitability Groups and Ratings for Agriculture

Sl.No	Soil Family	Soil Suitability Groups	Suitability Ratings
1	PUTP- Paralithic Ustropepts	Moderate	95
2	ECHSV- Entic Haplusterts	Good	100
3	ULPSF- Ultic Paleustalfs	Good	100
4	THSF- Typic Haplustalfs	Good	100
5	PUOT-Paralithic Ustrothents	Moderate	95
6	TUTP- Typic Ustropepts	Poor	75
7	LUOT- Lithic Ustrothents	Moderate	95
8	UUOP- Ultic Ustrochrepts	Moderate	95
9	THSV- Typic Haplusterts	Moderate	95
10	ECHSV- THSF	Good	100
11	PUOT- PUTP	Moderate	95
12	PUOT- TUTP	Moderate	95
13	PUTP- THSF	Moderate	95
14	THSF- ULPSF	Good	100
15	TUTP- PUTP	Poor	75

Source: Report of the Soil Testing Laboratory, Dindigul.

As per the suitability rating, the soil families of the study area are grouped as Group I, II and III (Julius Gy. Fabos and Stephanie J. Caswell. 1977) (Figure 4).

From the figure, the following inferences are drawn.

1. Soil Suitability Group I (High) with a rating of +100 includes soils that have few limitations that restrict their use. Otherwise, it is good for agricultural activities.
2. Soil Suitability Group II (Moderate) with a rating of +95 includes soils that have some limitations that reduce the choice of plants or require moderate conservation practices. Therefore, one has to give due importance in choosing plants, even though other factors are found to be suitable for agricultural purposes.
3. Soil Suitability Group III (Low) with a rating of +75 includes soils that have severe limitations that reduce the choice of plants or require special conservation practices or both.

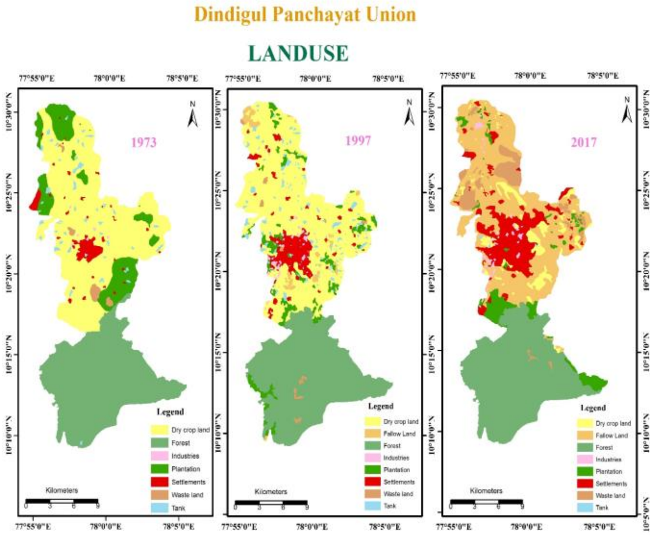
From the Figure 4, it could be observed that the soil suitability for agriculture is high (Group I) in Periyakottai, Mullipadi, Ammakulathupatti, Thadikombu, Thamaraipadi, Agaram, Balakrishnapuram, Adiyanuthu, Thottanuthu, Vellodu and Pallapatti village panchayats occupying an area of 87.14 Sq.Kms, that is 23.01 percent of the geographical area of the study area. It is low (Group III) in small parts of Agaram, Thadikombu, Chettinaickanpatti and Anaipatti village panchayats together covering an area of 17.43 Sq.Kms, ie., 4.60 percent of the total geographical area of the study area. The soil suitability for agriculture under the moderate (Group II) class occupies the remaining major parts of the study area, covering an area of 274.14 Sq.Kms ie., 72.39 percent of the study area.

In the light of the above observation, it could be stated that the soil suitability for agriculture that fall under moderate class (Group II) covers the major parts of the study area.

Land use Detractor Ratings

The land use maps of 1973, 1997 and 2017 are shown in the figure 5.

Fig 5 Dindigul Panchayat Union-Land Use-1973, 1997, 2017



The land use types are aggregated into different land use detractor groups and their respective detractor ratings in 0-100 scale are given in Table 2.

Table 2 Land Use Detractor Groups and Ratings for Agricultural Productivity

Sl. No	Land use type	Land use Detractor Groups	Detractor Ratings
1	Dry Crop land	Moderate	- 10
2	Fallow land	Moderate	- 5
3	Forest	Poor	- 20
4	Industries	V.Poor	-100
5	Plantation	Poor	- 20
6	Settlements	V.Poor	-100
7	Tanks	V.Poor	-100
8	Wasteland	V.Poor	-100

This aggregation is based upon the estimated similarity of land use types in terms of degree to which they modify the natural productivity of the soil for agriculture and the likelihood of their reverting or the effort required to revert them to agricultural use.

Similar land use types form a single land use detractor group. A total of five land use detractor groups are generated in this way. Assigned detractor ratings expressed on a 0-100 scale (i.e., minimum to maximum detraction) indicating the relative difference among land use detractor groups (Julius Gy. Fabos and Stephanie J. Caswell. 1977).

Land use Detractor Group I with a rating of 0

Land use in this category have noticed a detrimental effect on the agricultural productivity of the land. Land under wet crop area fall under this group. This group is absent in the study area.

Land use Detractor Group II with a rating of -5

This land use has a minimal detrimental effect on the value of agricultural land. A small amount of work is necessary to prepare the land for agriculture. Land under fallow land fall under this group.

Land use Detractor Group III with a rating of -10

More work is needed to rehabilitate the land use under this category so that it can be used for cultivation of crops. The land under dry crop land come under this group.

Land use Detractor Group IV with a rating of -20

The soil under this land use group is well protected by a cover of vegetation and is therefore in good condition. However, a considerable amount of clearing work must be done in order to bring the land to agricultural use. The land use under plantation area and forest fall under this group.

Land use Detractor Group V with a rating of -100

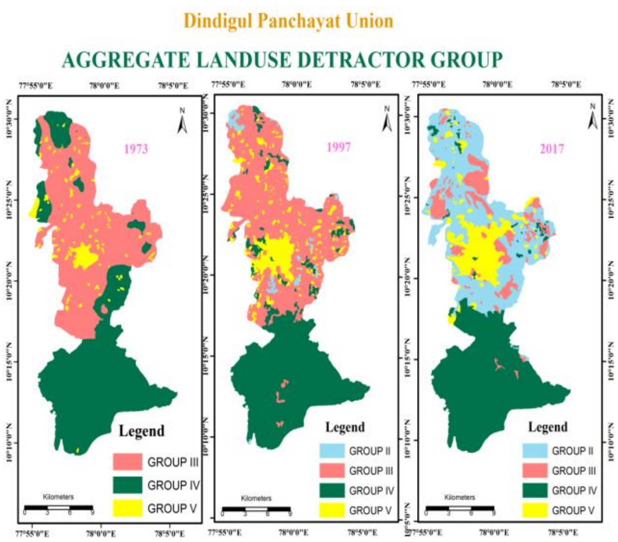
In this category, the agricultural value of the land is destroyed. The soil is physically removed or ruined or built over. It is socially and economically impossible to bring this type of land under agricultural use. Land use types like waste land, settlements, industries and water bodies come under this group.

As per the detractor rating, the spatial distribution of land use classes of the study area is grouped into Groups I, II, III, IV and V for the year 1973, 1997 and 2017 as shown in Table 3 and Figure 6.

Table 3 Area Under Detractor Ratings of Land Use Classes

Sl.No	Landuse Detractor Group Ratings	Area (Sq.Kms)		
		1973	1997	2017
1	0	0	0	0
2	-5	0	14.23	133.28
3	-10	170.75	169.49	19.94
4	-20	182.16	158.61	158.18
5	-100	25.80	36.38	67.31

Fig 6 Dindigul Panchayat Union – Aggregate Land Use Detractor Group



From Table 3 and Figure 6, the following inferences are drawn.

Land use Detractor Group I

This group is absent in the study area.

Land use Detractor Group II

This group was not noticed during the year 1973. In 1997, it occupies an area of only 14.23 Sq.Kms (3.76 %) and in 2017, it has increased to 133.28 Sq.Kms (35.19 %) in the study area.

Land use Detractor Group III

This group occupies 170.75 Sq.Kms (45.09%) in 1973 and has decreased to 19.94 Sq.Kms (5.27%), in 2017.

Land use Detractor Group IV

This group covers 182.16 Sq.Kms (48.10%) in 1973 and has decreased to 158.18 Sq.Kms (41.77%), in 2017.

Land use Detractor Group V

This group covers 25.80 Sq.Kms (6.81%) in 1973 and has increased to 67.31 Sq.Kms (17.77%), in 2017.

Determination of Normalized Resource Value Ratings

The resource value ratings are normalized to 0-100 scale, which is obtained from the interaction of the soil suitability groups and the land use detractor groups. The following formula is used for this determination.

$$X = \frac{[(s - t) + 75] * 100}{175}$$

All possible normalized ratings for agricultural productivity using soil suitability and land use calculated for the years 1973, 1997 and 2017 are presented in a matrix form (Tables 4, 5, and 6).

Table 4 Normalized Resource Value Ratings for Agriculture - 1973

Land use Detractor Group and Ratings		Soil Suitability Group Ratings		
		I (100)	II (95)	III (75)
I	(0)	-	-	-
II	(-5)	-	-	-
III	(-10)	94	91	80
IV	(-20)	89	86	74
V	(-100)	43	40	29

Table 5 Normalized Resource Value Ratings For Agriculture - 1997

Landuse Detractor Group and Ratings		Soil Suitability Group Ratings		
		I (100)	II (95)	III (75)
I	(0)	-	-	-
II	(-5)	97	94	83
III	(-10)	94	91	80
IV	(-20)	89	86	74
V	(-100)	43	40	29

Table 6 Normalized Resource Value Ratings for Agriculture - 2017

Land use Detractor Group and Ratings		Soil Suitability Group Ratings		
		I (100)	II (95)	III (75)
I	(0)	-	-	-
II	(-5)	97	94	83
III	(-10)	94	91	80
IV	(-20)	89	86	74
V	(-100)	43	40	29

Aggregate Normalized 0-100 Resource Value Ratings into A-B-C Classes

This aggregation serves to categorize 0-100 ratings in terms of 3 levels of relative potential resource value. These are high potential for agricultural productivity, moderate potential for agricultural productivity and low potential for agricultural productivity zones (Julius Gy. Fabos and Stephanie J. Caswell. 1977). The aggregate normalized resource value ratings are arrived for the study area and are shown in Table 7.

Table 7 Agricultural Resource Value Rating Aggregated into A-B-C Classes

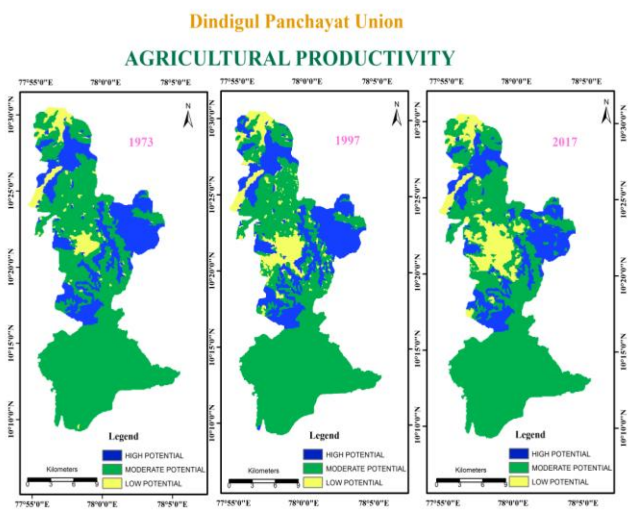
Sl. No	Resource Value Ratings	Aggregated Classes
1	89-100	A-High Potential for Agricultural Productivity
2	80-88	B-Moderate potential for Agricultural Productivity
3	0-79	C-Low Potential for Agricultural productivity

The following Table 8 gives the area under aggregated classes for agricultural productivity during the years 1973, 1997 and 2017. The spatial overlaying of aggregated soil suitability map with aggregated land use maps using ARC/GIS software is done to arrive at the agricultural productivity map of Dindigul panchayat union during the years 1973, 1997 and 2017 and the same is shown in Figure 7.

Table 8 Area Under Aggregated Classes for Agricultural Productivity

Sl. No	Aggregated Classes for Agricultural Productivity	Area (Sq.Kms)		
		1973	1997	2017
1	A-High Potential	87.26	92.80	55.83
2	B-Moderate Potential	263.94	244.47	253.91
3	C-Low Potential	27.51	41.44	68.97

Fig 6 Dindigul Panchayat Union – Agricultural Productivity



From Table 8 and Figure 7, the following inferences are drawn.

Class A

It is an aggregation of resource value rating of 89-100, which represents a high potential for agricultural productivity. Under normal farming practices, greater levels of production are associated with high fertility soil, which can be represented as prime agricultural land.

From the above observation, it could be stated that the area under the high potential of agricultural productivity class has decreased from 23.05 percent to 14.74 percent between 1973 and 2017. This loss in the area under the high productivity class is identified around Dindigul (Corporation) area especially in Thadikombu, Pallapatti, Adiyanuthu, Balakrishnapuram, Kurumbapatti village panchayats and in random throughout the study area.

Class B

It is an aggregation of resource value rating which represents the moderate potential for agricultural productivity. Class B landscapes are those to which planners and other decision-makers would turn. The availability for land is made less attractive to society because natural soil productivity is not particularly high.

From the above observation, it could be stated that the area under the moderate potential of agricultural productivity class in the study area has slightly decreased between 1973 (69.69 percent) and 2017 (67.05 percent). This loss is seen throughout the study area.

Class C

This is an aggregation of resource value rating which represents the low potential for agricultural productivity. Class C landscapes are those in which all probability will never be worth and an enormous cost is needed to put this land use type under production. These landscapes are either naturally unproductive for traditional crops or irreversibly allocated to other uses like, residential neighborhoods, shopping centers or industrial parks.

From the above observation, it could be observed that the area under low potential of agricultural productivity class in the study area has increased between 1973 (7.27 percent) and 1997 (18.21 percent). This increase in the area under low potential of agricultural productivity is predominantly noticed in and around Dindigul (Corporation). It is also seen in Pallapatti, Adiyanuthu, Balakrishnapuram, Chettinaickanpatti, Silapadi and Agaram village panchayats and also found scattered over the study area.

In Dindigul (Corporation), Pallapatti and Adiyanuthu village panchayats, the location of leather tanning industries, could also be the cause for the low potential of agricultural productivity. The toxic tannery effluents have deteriorated the quality of soil and land use. But in the rest of the areas in the study area, the cause for the low potential of agricultural productivity may be due to the inadequate and unreliable rainfall, low fertility soil, the spreading of polluted toxic tannery effluents through ground water stream, irrigating the agricultural lands using the available polluted ground water, the conversion of fertile land to other purposes like building constructions, poor socio-economic conditions of the farmers, lack of knowledge of farmers in applying the modern technologies and low level of literacy among the farmers.

6. Recommendations

The following recommendations are suggested for improving the agricultural productivity in the study area.

- Proper land improvement and reclamation methods would improve the agricultural productivity of an area.
- Land holding size plays a vital role in determining the agricultural productivity of an area. Fragmentation of land should be avoided. Equal farm size distribution would pave way for higher agricultural productivity.
- Small and marginal landholders may use bio fertilizers to avoid high cost fertilizers and can save the rural economy and the environment. Use of coconut coir and piths, neem seed kernel, neem seed oil cake and groundnut oil cake can also increase the soil potential considerably.
- Regulation of land rents may help the poor farmers to produce more agricultural products.
- Fertilizer consumption determines the growth of a crop. But recently it is observed that the use of chemical fertilizers may damage the quality of ground water and soil. Hence increased use of green manure consumption will enhance the agricultural productivity of a region.
- Bio fertilizer and compost may stabilize the fertility of the land.
- Pesticide consumption at the proper time also helps to increase the agricultural productivity.
- Chemical fertilizers use has to be avoided so as to improve the agricultural productivity and to protect the underground water and soil from further degradation.
- Natural farming using herbal pesticides will protect the microorganisms in land.
- Using plant protection chemicals to the crops may help the farmers engaged in agricultural activities.
- Pest attack recommendations suggested by the agricultural department should be followed.
- Use of hybrid yield varieties is suggested for the cultivators.
- Cost of seeds should be minimized, so that the poor farmers will be benefited.
- Seed processing and grading should be done.

- Periodical soil and water testing has to be done. Based on this the crops suitable for cultivation can be selected. Soil and water testing also help in further plant protection measures.
- Latest farm practices like ridge and burrow method, picture picker irrigation, sprinkler and drip irrigation methods can be followed.
- Using machineries like tractors, tube wells and agricultural implements are recommended for the increasing agricultural produce.
- Proper soil management is the dire need for increasing the agricultural productivity.
- Soil enrichment can be made by following effective irrigation systems that includes drip and sprinkler irrigation.
- Replacing low water requirement crops can help in increasing the agricultural productivity of an area.
- Some crops like cotton, oil seeds, saffron, onion, spices, chillies, ginger, tobacco and turmeric etc occupy smaller area but their returns in terms of money are always substantial. Hence the cultivation of such crops may significantly change the level of productivity of a component areal unit.
- Improved farming practices and best-suited technologies like, agro-horticulture, silvi-pasture and agro-forestry can be followed to improve the agricultural productivity.
- Dry farming technologies such as soil and water conservation measures are also suggested.
- Water harvesting techniques can be followed.
- Water irrigation management should be followed. Rain water method and moisture retention activities can be done for rainfed crops. Periodical watering and adequate watering of the plants -can be done for irrigated crops.
- Water management plays a vital role in cultivation. It should not be exceeded or decreased than the required limit.
- Policies should be framed in adopting suitable restriction on the use of vulnerable lands. This can be better achieved through national spirit and co-operation with technical experts, planners, administrators and active participation of farmers.
- Cultural practices like removal of weeds should be done in summer season.
- Inter cropping method can be adopted. For example, grams can be cultivated in between cotton crop. Low capital-intensive crops such as pulses may be cultivated in larger area.
- Crop rotation method can be followed. This will enrich the soil fertility.
- Crop planning should be done before commencing the cultivation. Based upon the soil and water tests, market requirement and season, the crops should be selected for cultivation.
- Boundary plantation can also be followed and would in turn reduces the wind velocity, give shelter, can also be used as a green manure and it gives additional income too.
- Unseasoned sowing should be avoided.
- Native trees, which need less water, may also be planted on all fallow and waste lands. Neem is the best native tree that can be grown in any type of soil.
- Medical plants are gaining popularity in India and abroad. Farmers can cultivate medical plants in large scale on their lands, as they need minimum amount of water. Indigenous medical plants like Indigofera tinctoria, Adhatoda vasica, Recinus communis, Aloe vera, Catheranthus roseos, Ocimum sanctum and Phyllanthus emblica. These medicinal plants have a high demand in local and foreign markets.
- Jatropha plant is recommended in waste lands of the study area. The oil obtained by crushing its seeds is so ideal for conversion into biodiesel. With global warming becoming a cause for concern and with petroleum reserves dwindling, our government is stepping up research in biodiesel. Apart from this, it gives additional income to the farmers.

7. Conclusion

Based on the results, it could be concluded that the agricultural productivity of the study area has decreased between 1973 and 1997.

Hence, it is the right time to make rational and sustainable use of each parcel of land according to its capability. To cope up with this, new farming techniques and agricultural practices should be introduced to improve the agricultural productivity in the study area.

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