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Applying Fuzzy Logic to the Estimation of Environmental Degradation Trends in Iran

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Abstract

During recent years several attempts have been made to incorporate environmental and natural resources degradation into national accounts. GNP as measured by the traditional system of national accounts does not consider environmental degradation caused by inefficient exploitation of natural resources. While the complete omission of environmental impacts is not possible, there could be an optimal level of environmental degradation. However, environmental degradation cannot be quantified easily. Therefore, there is a need for a different approach to estimate the level of environmental degradation so that it can be accounted for in the GNP. In such cases where sufficient data are not available, especially for the past, the fuzzy logic method is practical. This paper applies the fuzzy set theory to estimate the trends of environmental degradation in Iran in the period 1959-1998.

Keywords: Environmental Degradation, Fuzzy Sets, Green GNP, National Accounts, Exhaustible Resources, Renewable Resources

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1- Introduction

GNP as a measure of national macroeconomic performance is determined on the basis of the System of National Accounts (SNA). However, the SNA (1968) doesn't consider environmental degradation caused by inefficient exploitation of natural resources. With the increasing salience of environmental concerns, a general consensus has emerged among policy-makers and national statistical officers that the environmental impact of economic activities must be incorporated into the national accounts in some way. This would provide a systematic way of reporting and monitoring these activities. This consensus is referred to in the *Handbook of Integrated Environmental and Economic Accounting* provided by the United Nations' Statistical Division (UNSD, 1993, p.iii).

Since the mid-1980s, a wide range of methods have been put forward to accounting for the environmental impacts in the national accounts. These measures add imputed values for the depletion of natural capital (k_n). (Adger, 1992; Bartelmus *e. al.*, 1993; Repetto *et al.*, 1989; Solorzano *et al.,* 1991; Van Tongeren *et al.,* 1993). All of these cited studies can be found in: *Toward Improved Accounting for the Environment* (Lutz, 1993).

The System of Environmental and Economic Accounts (SEEA) set out in UNSD (1993) treats environmental changes to be entered in the asset accounts and net change in these as an entry in the flow accounts. The depletion and degradation of environmental resources could be regarded as loss of natural capital and subtracted from GNP to reach an environmentally-adjusted GNP (ENP), where:

ENP=GNP- Environmental Costs

Environmental National Product (ENP) is the highest aggregate value of final goods and services produced within a given period by domestically-owned factors of production and environmental capital in current prices (Choi, 1994).

If GNP is regarded as a measure of welfare, then damage costs are correct measures for calculating the loss of welfare resulting from environmental damage. However, Linnot (1999:184-185) suggests that there is no clear positive relationship between consumption and welfare at all.

The different views about the role of GNP lead to two separate approaches (Ekins, 2001, p.68):

1. GNP is an indicator of production not welfare. To complete this indicator, the UNDP has provided the Human Development Index (HDI) which consists of various measures of income, education and life expectancy.
2. GNP is an imperfect welfare indicator, so sometimes it must be added to or subtracted from it various elements to reach a perfect indicator.

In this regard, Nordhaus and Tobin (1973) for the first time provided a Measure of Economic Welfare (MEW). Then, 16-years later, Daly and Cobb (1989) calculated an Index of Sustainable Economic Welfare (ISEW). Cobb and Cobb(1994), Stockhammer *et al.* (1997) computed the ISEW for Austria, as did Castaneda (1999) for Chile; Diefenbacher (1994) for Germany; Guenno and Tiezzi (1998) for Italy; Rosenberg and Rosenberg *et al.* (1995) for the Netherlands; Moffatt and Wilson (1994) for Scotland; Jackson and Stymme (1996) for Sweden; and Jackson *et al.* (1997) for the UK. In an analysis about ISEW and GPI, Neumayer (2000) has referred to the recent studies.

An approach developed in the Netherlands; called NAMEA (National Accounting Matrix including Environmental Accounts) presents data in a way that mirrors the national structure so as "to provide a complete account of all linkages between changes in the environment and the transactions recorded in the national accounts" (De Haan *et al.*, 1993).

By 1997, "NAMEA type tables" had been produced by Austria, Denmark, Finland, Germany, Sweden, and the UK as well as the Netherlands, with France, Luxembourg, Ireland and Portugal (EUROSTAT, 1997).

Ekins (2001) calls the difference between the current level of environmental impact from a particular source and the sustainable level of impact according to the sustainability standard "the Sustainability Gap≡ SGAP". The Overall Monetary SGAP (OMSGAP) for economic activity is an interesting indicator with which to make inter-country comparisons of environmental efficiency.

The valuation problems in green accounting are related to environmental externalities. At a theoretical level, one can use Pigouvian taxes to fully internalize external effects. These taxes measure the value of the depletion of environmental capital (Aronnson and Lofgren, 1999).

In natural resource dependent economies such as Iran, disregarding the effects on natural resources misleads policy-making. Therefore, to measure the environmental effects on national income, the amount of environmental degradation must be estimated or derived. Unfortunately, there is insufficient statistical data to explain environmental problems in Iran. Hence, the conventional econometric and statistical methods have not been used in this study.

The rest of this paper is organised as follows. Section two discusses the concept of environmental degradation and welfare. Section three explains the fuzzy set theory. Section four introduces the variables and the data. Section five applies fuzzy set theory to estimate the trend of environmental degradation. Finally, section six concludes the paper.

2- Environmental Degradation and Welfare

Environmental degradation occurs as a result of economic activities producing goods and services. Population pressure, inadequate agricultural land use, and free access to resources (such as fisheries) are among the main factors contributing to environmental degradation (Turner *et al.*, 1994). Inefficient exploitation of natural resources resulting in environmental degradation occurs mostly because of: the absence of a mechanism for compensating the negative external effects and market failures in pricing these impacts; and lack of laws regulating tenure and exploitation of resources or the ambiguity of such laws. The winners and losers of environmental degradation are two distinct affected groups. Winners are those who benefit from economic activities in terms of profits and wages, and losers are those who bear the costs of environmental pollution and loss of environmental amenities (Souri, 1999). Obviously, the perfect omission of environmental impacts of economic activities is not possible technically, so there is an optimal level of environmental degradation that is not zero.

Sustainable economic growth without degradation of the environment is feasible by accounting for negative environmental effects. Experience shows that it is possible to coordinate environmental management with economic growth. The declining trends of energy intensity (energy consumption divided by GDP) in the industrial countries is one manifestation of this reality.

The wasting or degradation of the environment corresponds to a diminution in the size of the environmental stock or capital. A ready measure of environmental stock size is the volume of pollutants suspended in the air year by year (Hartwick, 1991, p.642). This measure has a close relationship with Energy Intensity (EI) which we have used in the following sections. EI is increased with high consumption of energy. We follow the Barbier and Markandya (1990) approach for determining the relationship between welfare and environmental degradation. At any time, the rate of degradation ($\dot{s}$) is a function of: (1) the flow of waste (W) in excess of the amount assimilated by the environment (A) and (2) the flow of renewable resources harvested from the environment(R) in excess of the biological productivity of these resources (G), plus the flow of exhaustible resources extracted from the environment (E). Mathematically, this may be written as:

$$\dot{s} = f((W - A),(R - G + E)) \qquad (1)$$

The following assumptions are made about (1).

(i) It is a differentiable, increasing function of its arguments. As the net waste level increases and as the excess rate of harvesting (from pastures, forests and fish) increases, so does the level of environmental degradation.

(ii) It is a convex function of its arguments.

(iii) A sufficient condition of zero degradation and a sustainability criteria is W=A and (R+E) =G.

Now, we link the level of environmental degradation to the level of economic activity (consumption as a welfare measure) and the stock of environmental assets. In this regard, we have:

$$W=W(C),\ W' \succ 0, W'' \succ 0 \qquad (2)$$

$$A=A(X),\ A' \succ 0, A'' \prec 0 \qquad (3)$$

$$R=R(C),\ R' \succ 0, R'' \succ 0 \qquad (4)$$

$$E=E(C), \quad E' \succ 0, E'' \succ 0 \tag{5}$$

$$G=G(X), \quad G' \succ 0, G'' \prec 0 \tag{6}$$

Where C and X are consumption of goods and the stock of environmental assets respectively. So, W, R and E are increasing convex functions of C in consistency with material-balance models and A and G are increasing concave functions of X in consistency with optimal economic growth models under biophysical constraints. Substituting (2)-(6) into (1) yields the following equation:

$$\dot{S} = h(C,X) \tag{7}$$

Where

$$h_C \succ 0, h_{CC} \prec 0, h_X \prec 0, h_{XX} \succ 0, h_{CC} h_{XX} - h_{CX}^2 \succ 0.$$

Therefore, $\dot{s}$ is an increasing concave function of C and decreasing convex function of X. On the other hand:

$$\dot{x} = -a\dot{s}, X(0) = X0, X(\infty) \text{ is free.} \tag{8}$$

Where a is a constant scalar. Thus, there is an inverse relationship between the rate of environmental degradation ($\dot{s}$) and the change rate of environmental stock ($\dot{X}$).

Based on consumption and environmental stock, we can write the following utility function:

$$U=U(C, X) \tag{9}$$

Where:

$U_C \succ 0, U_{CC} \prec 0, U_X \succ 0, U_{XX} \prec 0, U_{CX} = 0, \lim U_C = 0, \lim U_X = 0,$ If C and X approach to ∞. Here, utility is an increasing concave function of C and X; marginal utility of C is not correlated with X, and in the indefinite horizon, C and X approach to zero.

Our planning problem is:

$$\text{Max} \int_0^\infty e^{-rt} U(C, X) dt \qquad (10)$$

Subject to: $\dot{x} = -a\dot{s}$, $X(0)=X_0$, $X(\infty)$ is free.
Hamiltonian function of this problem is:

$$H = e^{-rt}(U(C,X) + p(-ah(C,X)) \qquad (11)$$

Where

P is a Lagrange multiplier. For this problem, they show that the first order conditions are:

$$\frac{dc}{dx} \succ 0 \quad \text{If} \quad h_{CX} \prec 0.$$

In this way, there is a positive relationship between degradation and consumption. So, the increasing consumption (as a welfare indicator) results in more environmental degradation.

To estimate environmental degradation, it must be taken into account that environment is not quantified easily. Pollution, aesthetic values of the environment and its resources cannot be easily valued in monetary terms. To quantify the environmental values, alternative methods such as hedonic pricing (Rosen, 1974), contingent valuation (Bohm, 1972), and travel cost analysis are used. Although information collected via Willingness to Pay (WTP) may provide biased estimates of the marginal environmental damage, empirical attempts to design green GNP welfare measure have to rely on the ability of current data to provide close approximation of the economy system.

Environmental degradation and green GNP have a strong relationship with each other. Environmental degradation, however, is difficult to measure because it is vague and uncertain.

We cannot determine the exact reference values of environmental degradation. So, a statistical valuation of vagueness must always be considered in the procedure of computation of environmental degradation. Because of its systematic approach to handling vague and multi-dimensional situations, the use of linguistic values based on the Fuzzy Logic (FL) methodology seems more suitable for computing environmental degradation (Munda, *et al.,* 1994, p.98).The fuzzy sets theory and fuzzy logic provide an acceptable method for assessing the trends of environmental degradation in Iran.

3- The Fuzzy Sets Theory

The fuzzy sets theory and fuzzy logic were introduced for the first time by Zadeh in 1965. Since then, this theory has been developed and has found applications in different disciplines such as electronics, computer and social sciences. The fuzzy sets theory is most applicable for uncertain conditions. The mathematical formulation of many concepts and vague or inexact variables, and reasoning and decision-making in uncertain environment is possible based on this theory.

Fuzzy uncertainty, in contrast with probabilistic uncertainty (with true or false statements), relates to events that have no well-defined and unambiguous meaning (Kosko, 1992). The fuzzy set theory is based on multi–valued logic (Zimmermann, 1991). Fuzziness describes the degree to which an event occurs, not whether it occurs.

A fuzzy set, by definition, is a set that the membership degree (smallness or greatness degree of belongingness the element to the set) of its members is continuously in the interval [0, 1] and each member of this interval is a membership degree. The nearness of membership degree to 1 indicates the greater belongingness to set and to 0 indicates the less belongingness to it (Zimmermann, 1991, pp.11-12). On this ground, fuzzy function is a mapping from real numbers set (R) to set [0, 1], by this formula:

$$F: R \rightarrow - [0, 1]$$

$$F = \{(x, m(x)) | x \in X\}$$

Where m(x) is membership degree of x and X is a universal set. In the above fuzzy set, if m(x) =1, then x is fully member of X and if m(x) =0, then x is not a member of X at all. Also, if m (x_1) is greater than m (x_2), then x_1 has more belongingness to X than x_2.

Height, area, price, quantity, volume, pressure, weight, population, distance and saving are variables that can be sketched in fuzzy sets framework. For example, if we consider the price variable, in verbal language, we say the price is high but if we treat it exactly we must ask how high the price is. Is a price of $100 high? Is a price $1000 high? In this way, we need to give a membership degree to these prices. Therefore, if we attribute 0.1, 0.25, 0.4, 0.65 and 0.98 to prices: $10, $50, $100, $300 and $1000, respectively, a fuzzy set will be produced as follows:

$$F = \{(10, 0.1), (50, 0.25), (100, 0.4), (300, 0.65), (1000, 0.98)\}$$

In this example, the higher the prices are, the greater the membership degrees is. In fuzzy sets, the concept of a linguistic variable is very important. A linguistic variable has 5 dimensional structure: 1) the name of variable; (2) terms set; (3) universal set; (4) rule; and(5) fuzzy set. In the above example, the name of the variable is price. Terms set is:

T (price) = {... very low, low, high, very high ...}.

If universal set is [0,1000], rule and fuzzy set is F that images 10 to 0.1,50 to 0.25 and so on.

In fuzzy sets, some ordinary inference laws, particularly inclusion and exclusion do not satisfy. Hence, in fuzzy set A and its complement (A'):

$$A \cap A' = \emptyset$$

$$A \cup A' = X$$

Where Ø is a null set and X is a universal set. Unlike the ordinary sets, the operators of fuzzy sets for the two sets A and B are:

Intersection:	$A \cap B = \text{Min}(m(x), n(x))$
Union:	$A \cup B = \text{Max}(m(x), n(x))$
Complement of A:	$A'(x) = 1 - A(x)$

Where m(x) and n(x) are membership degrees of A and B respectively.

Except for inclusion and exclusion laws, the other laws of classic sets [such as Commutative, associative, distributive, idempotence, absorption, involution ability, demorgan laws, implication, conjunctive, disconjunctive, negation and Cartesian product, combination, dilation and image] are satisfied in fuzzy sets (Zimmermann 1991,pp.23-38).

4- Data and Variables

Iran possesses various natural resources and a diverse climate. Table 1, classifies the natural resources of Iran. The numbers in the parentheses show the relative importance of resources. Single product structure of the Iranian economy and its dependence on oil revenues result in pressure on hydrocarbon resources. Because of the prevailing share of oil and gas in the exhaustible resources, the ratio of oil and gas revenues to real GNP is used for computing the index of exhaustible resources. To account for the other exhaustible resources, we apply the ratio of mines value added to real GNP. The energy intensity is another measure used for building the exhaustibility index.

Table 1: Classification of Natural Resources of Iran

Exhaustible resources	Share (%)	Semi-renewable resources	Share (%)	Renewable resources	Share (%)
Oil		Soil	71.7[2]	Water	29.3[2]
Gas	81[1]	Ecological system	-----	Forests and pastures	45[3]
Coal				Fisheries	55[3]
Mines	9[1]			Wind and Solar energy	----

Source :(1) and (3), Iran's National Accounts(2000);(2),Statistical Center of Iran(2000)

1) In terms of oil +gas +coal and mines value added,
2) In terms of total area of water and soil,
3) In terms of forests, pastures and fisheries value added.

Forests and pastures play different roles. Economically, other than the direct benefits of forests, the stabilization of CO_2, and provision of O_2 are also vital. Degradation of the forests and pastures has been worsened over the past decades. To construct the renewable resources index, harvested amount is used to show deforestation. Also, the number of animal units is applied to pastures. Fisheries are the other renewable resource. In fuzzy computations, we use the fisheries value added relative to real GNP.

Soil is a semi-renewable resource. Soil erosion is considered as depreciation of soil. However, in constructing the indices we ignore the soil because of data limitation. Therefore, our emphasis in this study is on two indices namely, renewable resources index and exhaustible resources index. These indices are defined in the following paragraphs.

Renewable resources index is defined as:

$$I_1 = \frac{RVFOR}{RGNP}\left(\frac{HAR}{FOR}\right) + \frac{RVDOM}{RGNP}\left(\frac{DOM}{PAS}\right) + \frac{RVFIS}{RGNP}\left(\frac{CATCH}{1}\right)$$

Exhaustible resources index is defined as:

$$I_2 = 0.7*\frac{TROIL}{RGNP} + 0.2*EI + 0.1*\frac{RVMIN}{RGNP}$$

Where RVFOR is forestry value added in constant prices (1990=100), RGNP is real gross national product (1990=100), HAR is harvest the forests (million *cubic* meters), FOR is the total forests area in the country (million hectares), RVDOM is the animal husbandry value added in constant prices (1990=100), DOM is the number of animal units (1000 animal units), PAS is the area of pastures in the country (million hectares), RVFIS is the fisheries value added in constant prices (1990=100), CATCH is the catch of fish (tone), TROIL is the total oil revenues in constant prices (1990=100), EI is the energy intensity in terms of supply of energy to GDP, and RVMIN is the mines' value added in constant prices (1990=100). The weights in calculating I_2 are based on nearly steady (or constant) shares of related components in a historical trend.

Choice and computation of these two indices are arbitrary and pertaining to existing data. The logical statements behind them are:

1. Deforestation increases with over harvesting of forests.
2. Pasture degradation is an increasing function of number of animal units.

3. Fish stock decreases by over catching.
4. Pressure on oil reserves induces the degradation of oil resources.
5. Higher energy intensity accompanies degradation.
6. More mining results in higher degradation of mines.

Figures 1 to 6 show the trends of variables $V_1 = \frac{DOM}{PAS}$, $V_2 = \frac{HAR}{FOR}$, $V_3 = CATCH$, $V_4 = \frac{TROIL}{RGNP}$, $V_5 = EI$ and $V_6 = \frac{RVMIN}{RGNP}$. As these figures show, the pressure on exhaustible resources was greater during the Iran-Iraq War (1980-1988) and during oil shocks. The first three figures indicate that environmental degradation has increased in renewable resources over the 1959-1999 period, but variable V4 is extremely affected by oil price fluctuations.

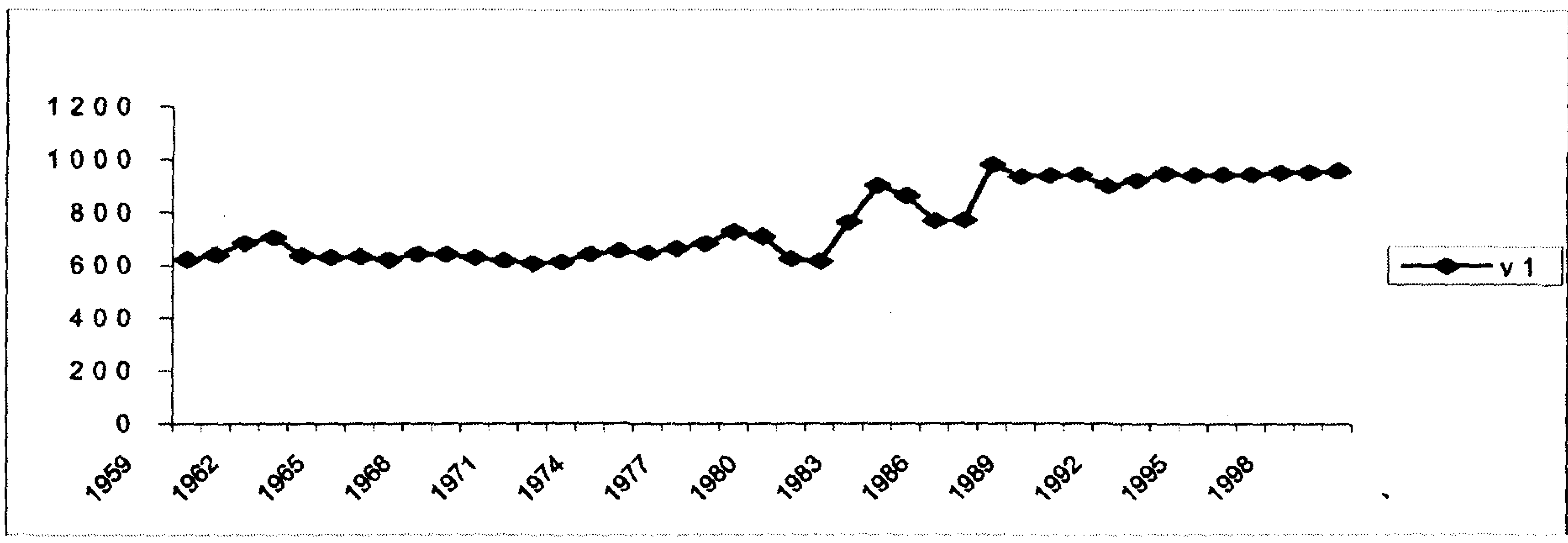

Fig 1: The Trends in Number of Animal units (1000 Animal units) Per Area of Pastures (Million Hectares) in Iran, 1959-1998 (V_1 = DOM/PAS)

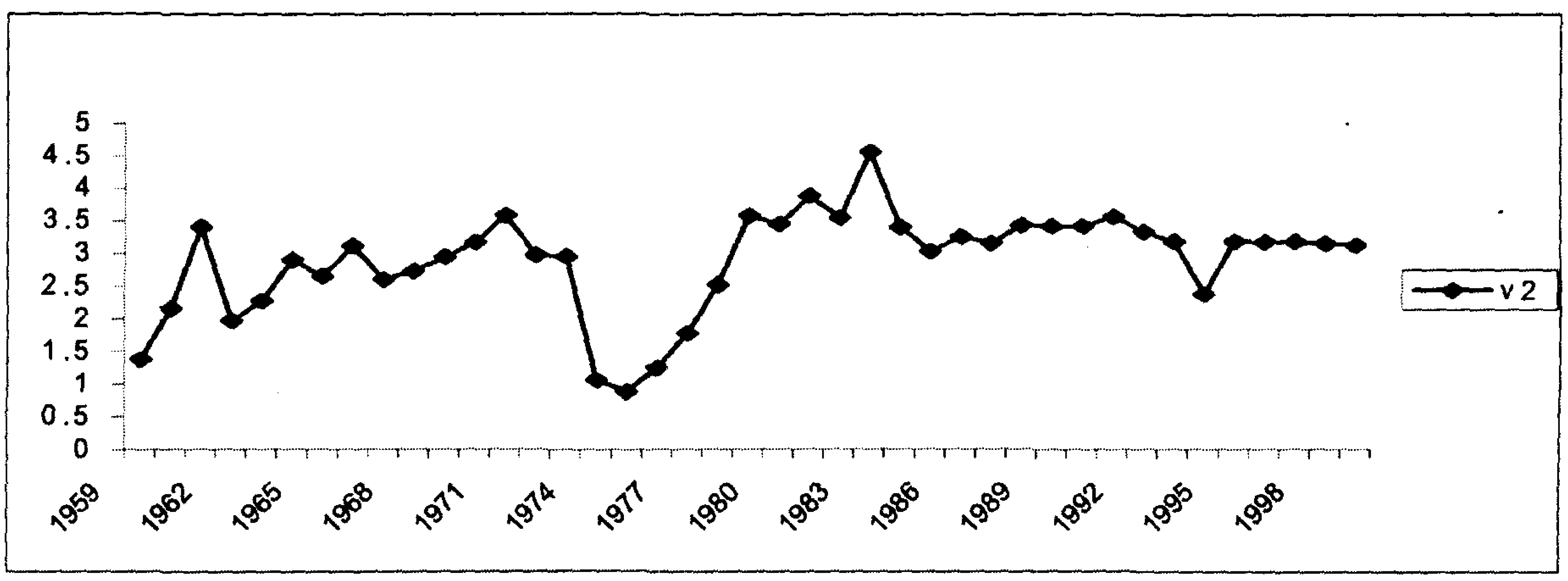

Fig 2: The trends in the amount of forest harvest (million cubic meters) per total forests area (million hectares) in Iran, 1959-1998, (V= HAR/FOR)

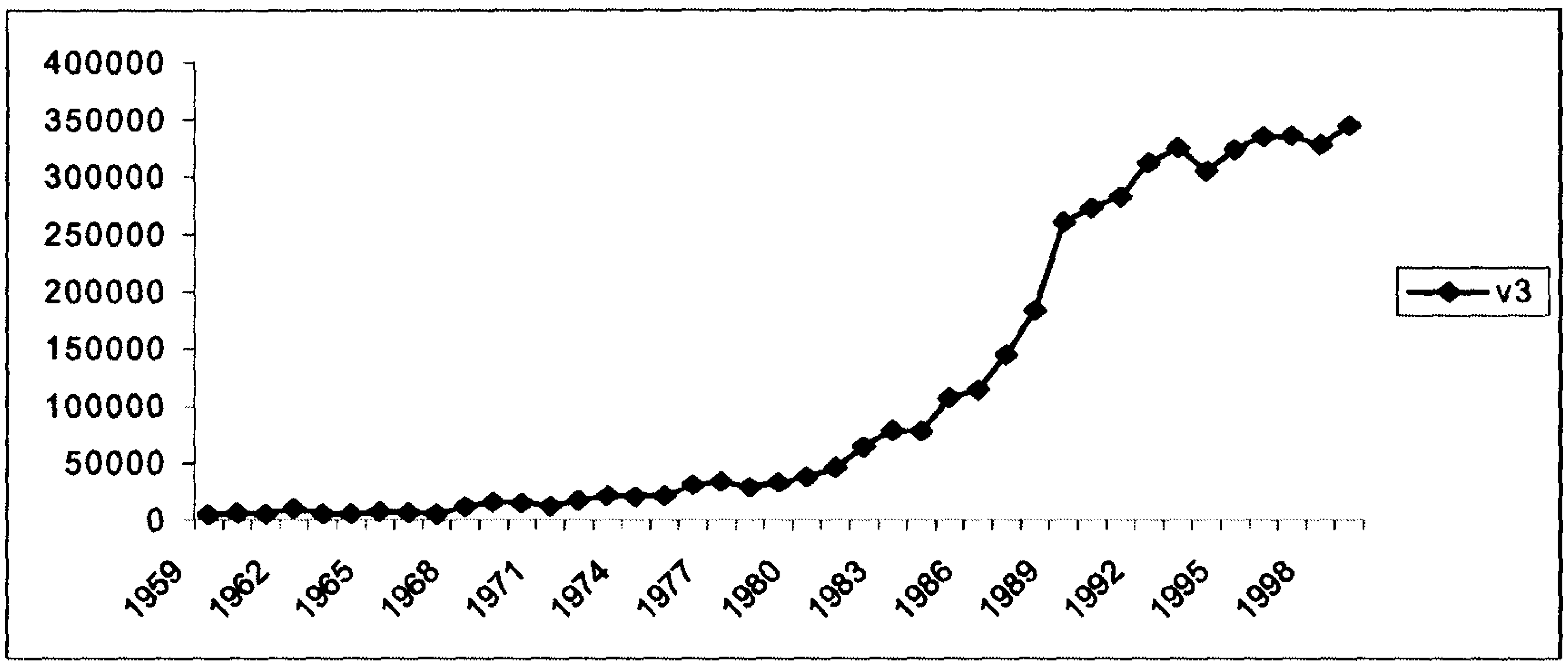

Fig 3: The Trends in Fish Catch (tons) in Iran 1959-1998, (V3 = CATCH)

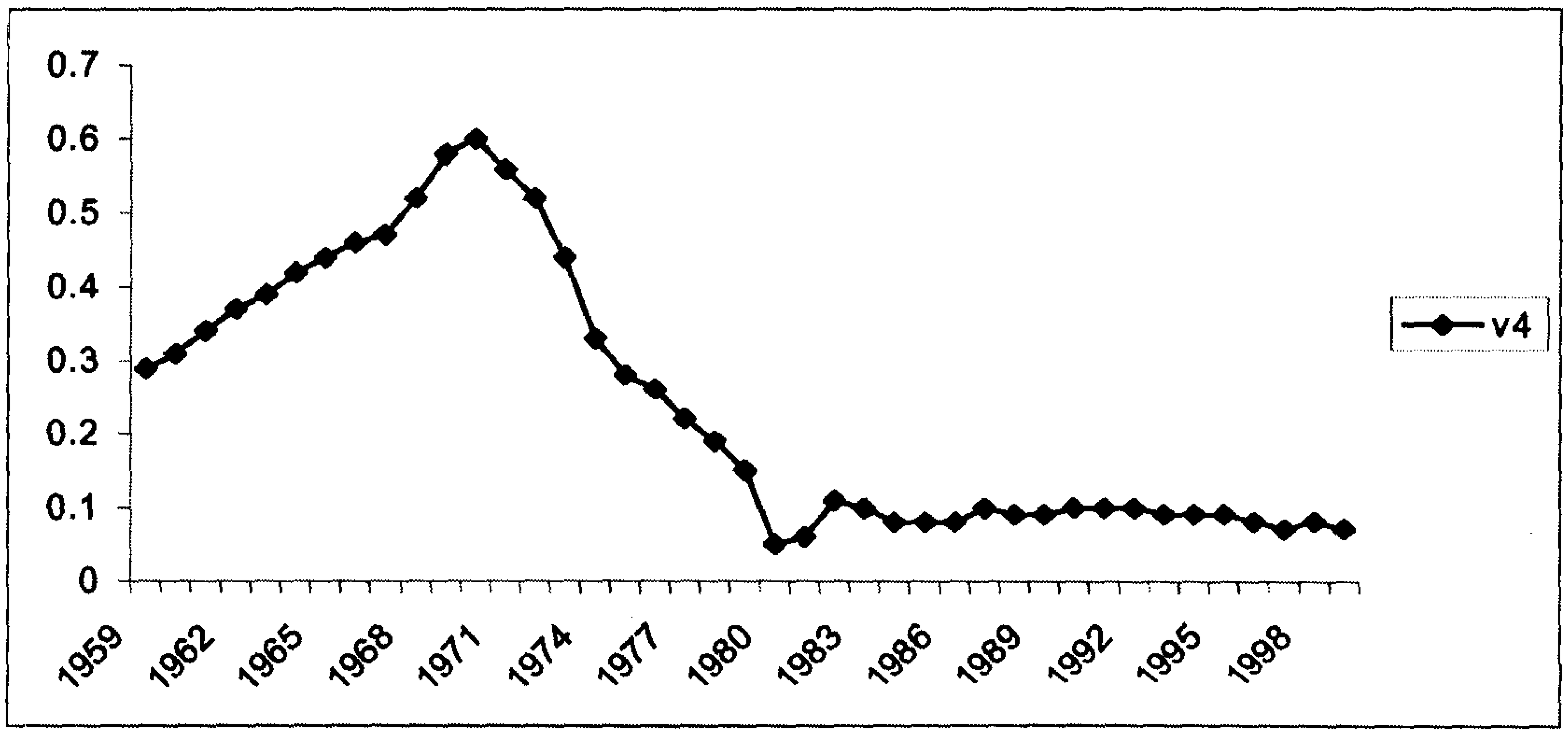

Fig 4: The Trends of Ratio of Real Oil Revenues (1990=100) to Real Gross National Product in Iran, 1958-1998 (V4 = TROIL/RGNP)

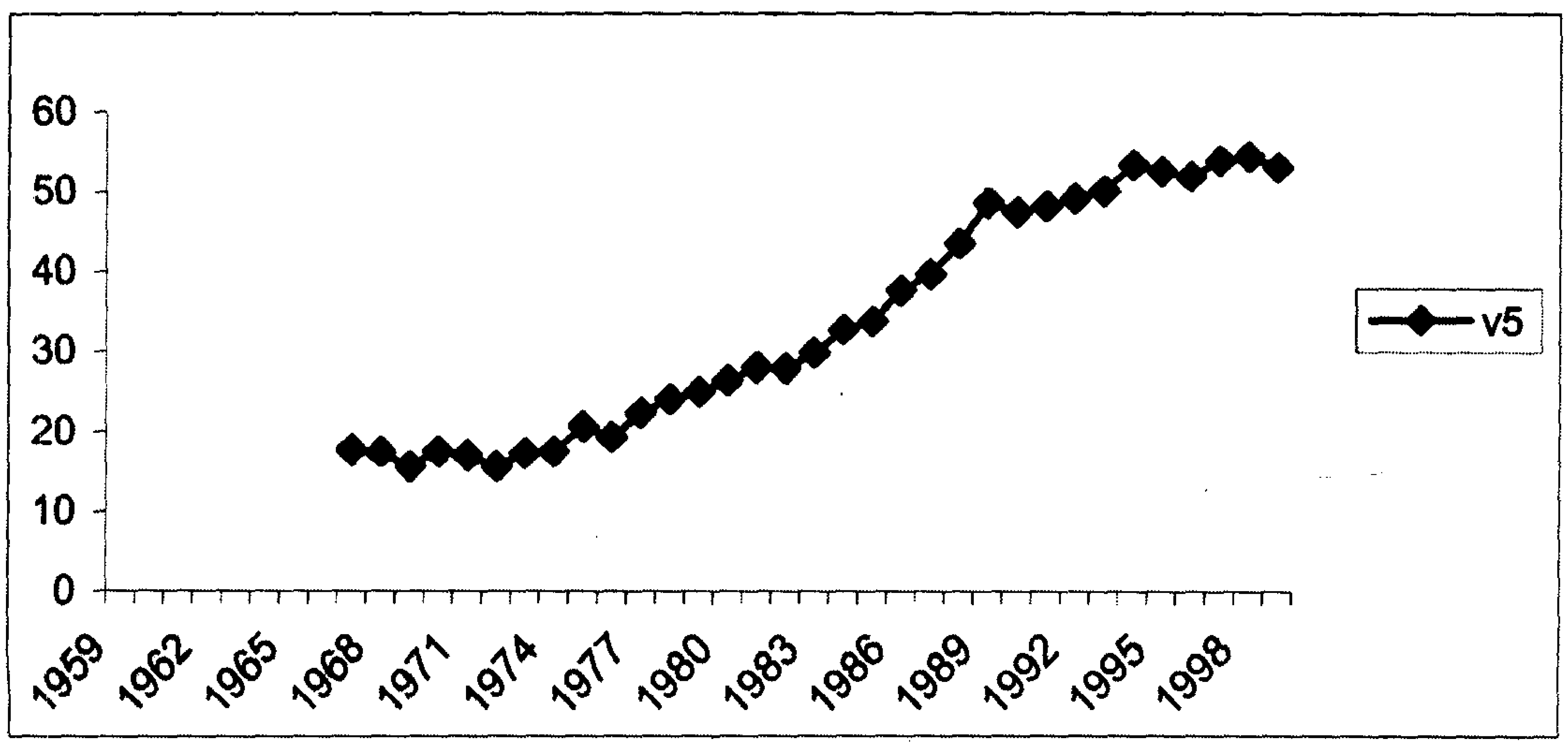

Fig 5: The Trends in Energy Intensity in Iran 1958-1998 (V5 = EI)

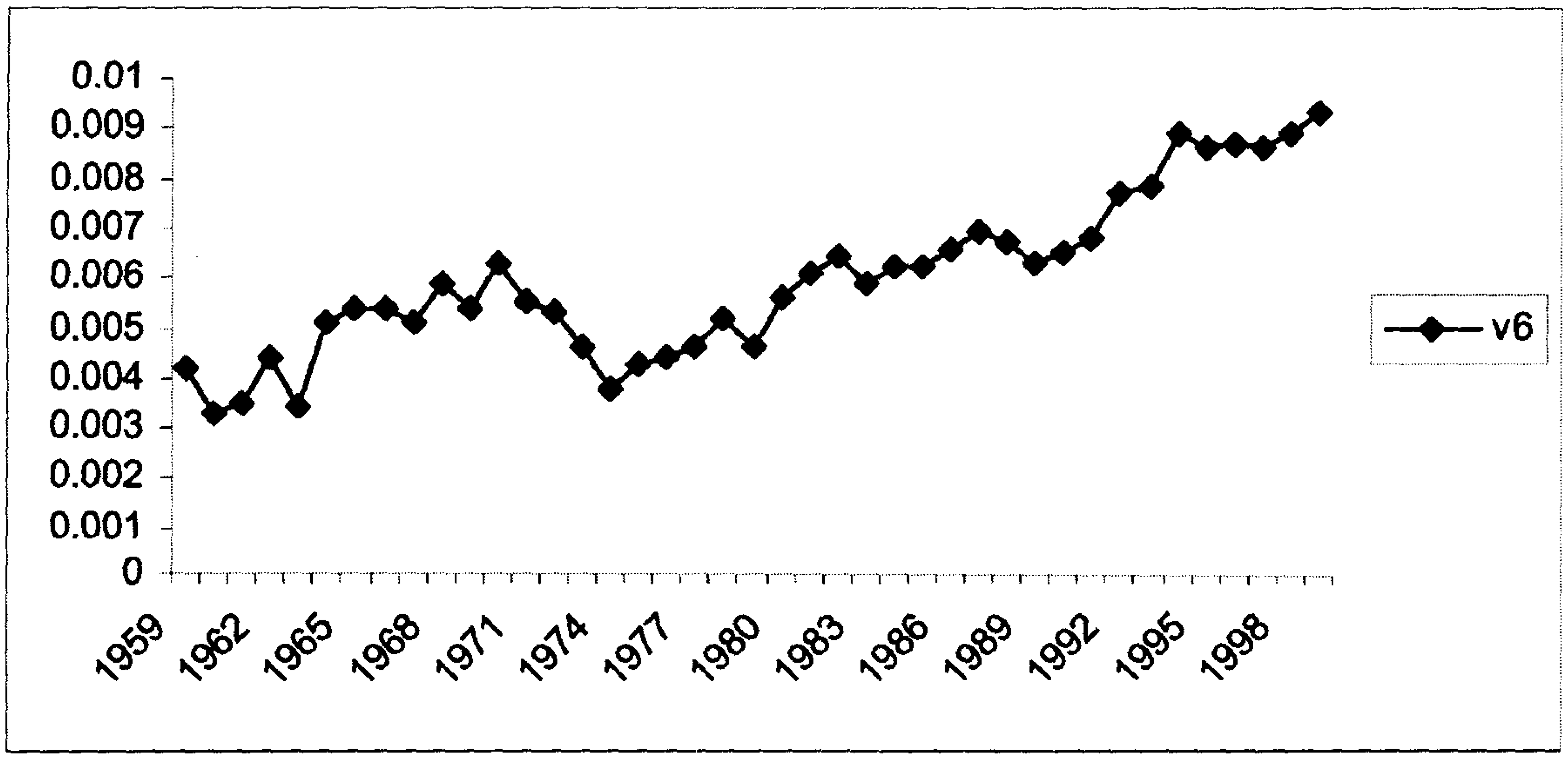

Fig 6: Trend of Mines' Value Added in Constant Prices (1990=100) Per Real gross National Product in Iran 1958-1999.

Figures 7 and 8 show the trends in the two indices I_1 and I_2. As seen, their increasing trend indicates the negative effects on the environment in Iran.

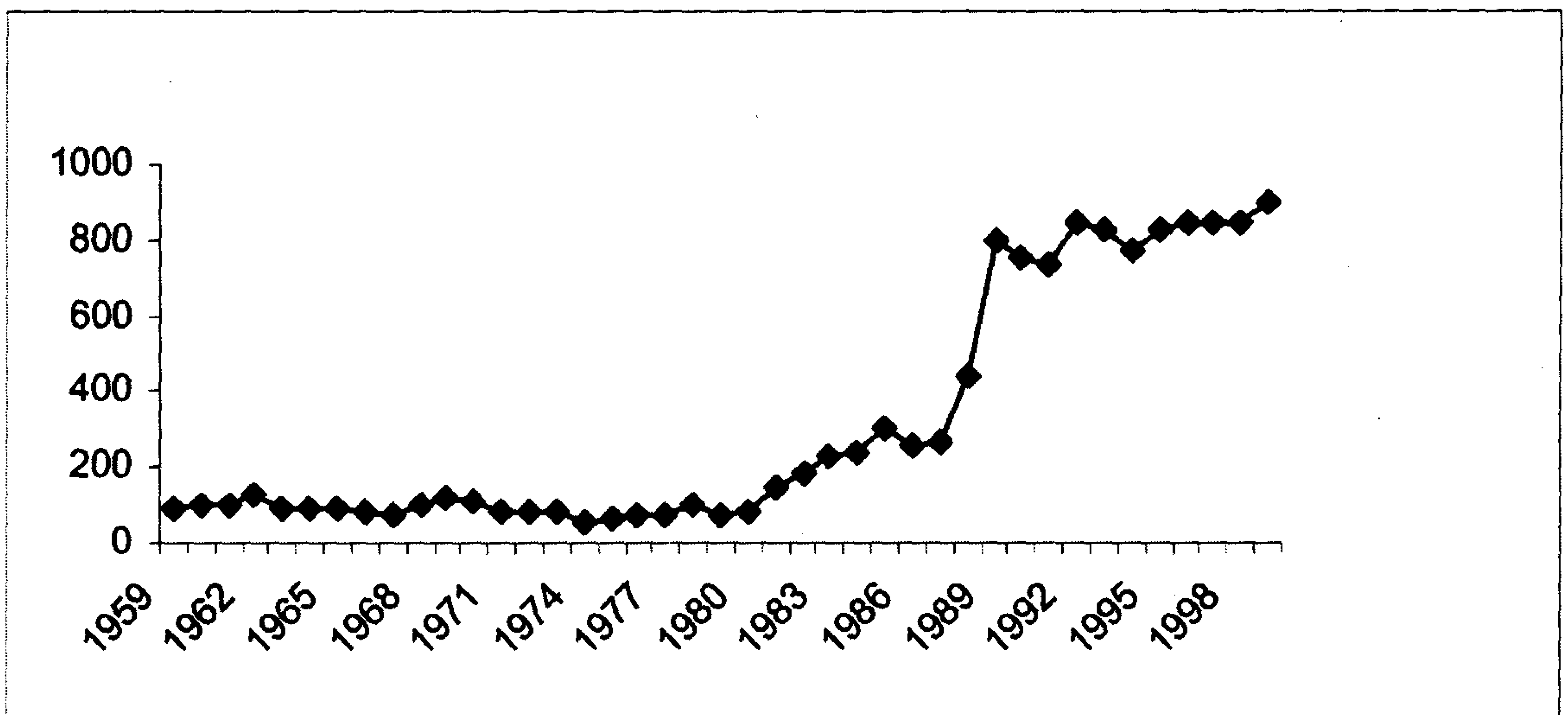

Fig 7: Renewable Resources Index(I1)

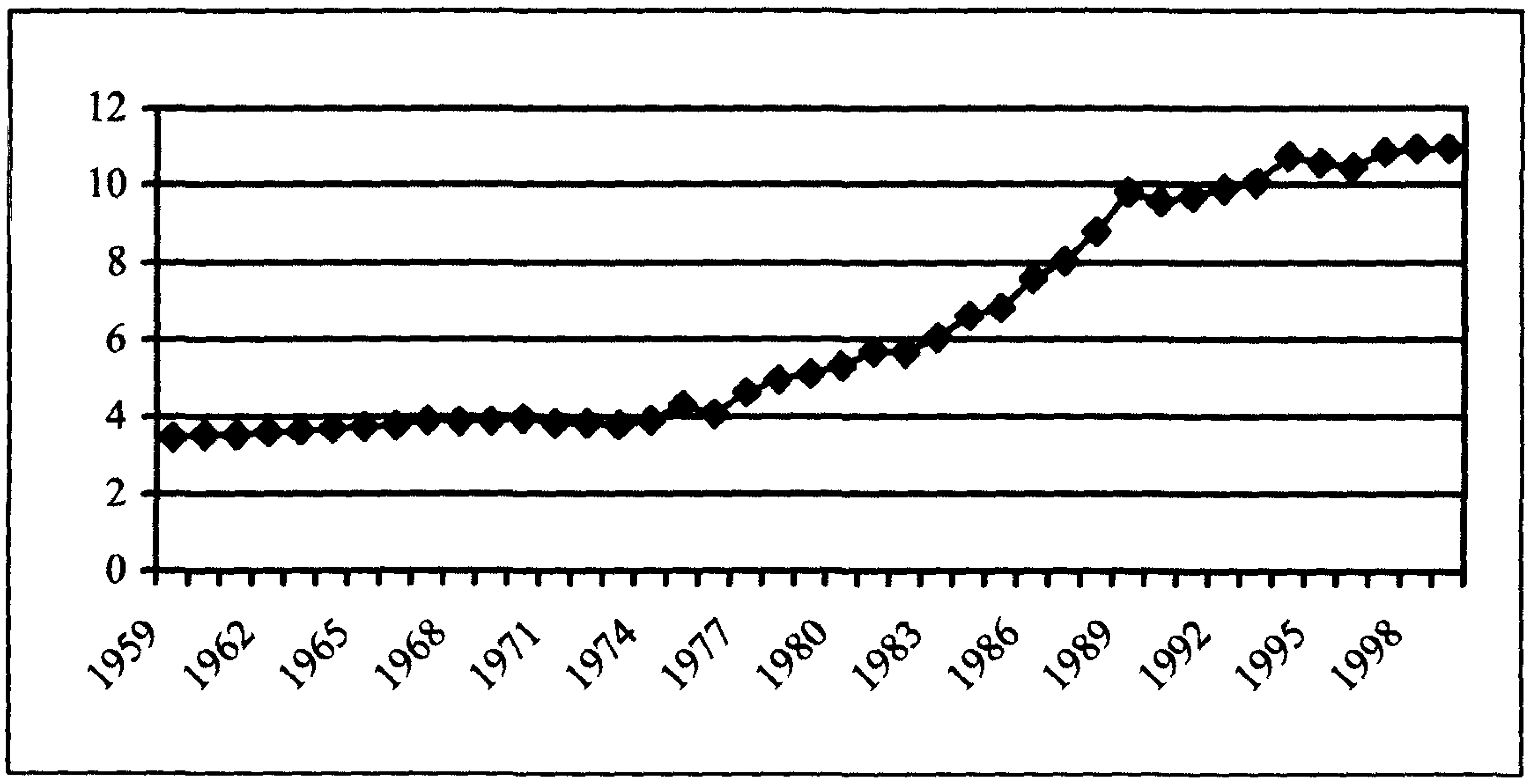

Fig 8: Exhaustible Resources Index (I2)

5- The Environmental Degradation Trends

As mentioned earlier the main purpose of this study is to estimate the trend of environmental degradation in Iran during 1959-1999. Since degradation has fuzzy nature and is not computable in a certainty context, instead of regression methods a fuzzy set approach is applied here. This set is supported by quantities of two previously developed indices of various variables. To construct the set, first the moving average of the two series (I_1 , I_2) with a 6-years lag[12] is computed to obtain the normal values for them. For example, in 1999 the moving average is the average of 1994-1999. Of course, instead of normal values, one can use median or mode. Then, we estimate the quantitative support levels by computing one and two standard deviation (SD) around the moving average. Also, three, four and more standard deviation is usable. For 1995, standard deviation of I_1 and I_2 are 45.74 and .474, respectively. Thus, for 1995, we have support levels in Table 2.

1- Number of lags is arbitrary. Since our goal is to obtain an [0,1] interval through normalizing, here we chose 6 lags arbitrarily.

Table 2: Support Levels of I1 and I2 in 1995

Very Low(VL)	Low(L)	Normal(N)	High(H)	Very High(VH)
-2SD	-1 SD	Mean	1 SD	2SD
I_1: 697.665	743.408	789.152	834.895	880.638
I_2: 9.142	9.616	10.09	10.564	11.038

Hence, by computing for each year two 5-member sets and in total a 10 *36[1] matrix is obtained. Each point in this set is called a break point.

Then, data values are linked to break points. The actual value of I_1 in 1995 is 825.68, and regarding the break points, the place of this actual value is somewhere between normal and high ranks. Here, 825.68 are supported by two levels [in fuzzy logic a particular value is supported by several levels]. In 1995, I_1 is both normal and high but how much normal and how much high? It depends on its relative place to break points. In fuzzy logic, creating the support levels is done by membership functions. Here, the following membership function is used:

$$\mu_{Xi} = \left| \frac{Xj - X}{SDx} \right|$$

Where, X is the actual value, X_i is a value nearer to X and X_j is another support level[2]. For the above example, X_i =834.895 and Xj =789.152, then:

$$\mu_{834.895} = \left| \frac{789.152 - 825.68}{45.74} \right| = 0.799$$

$$\mu_{789.152} = \left| \frac{834.895 - 825.68}{45.74} \right| = 0.201$$

So, the membership degrees of X1 and X2 are 0.799(correspondent with Normal rank) and 0.201(correspondent with High rank) respectively.

1- 36 is difference between 1999 and 1964 (by considering the lags).
2- Xi and Xj are substitutable.

In the former membership function, observations are assigned to maximum two levels: 1 with complete membership and 0 with non-membership.

Decision-making rules, show the combination of two particular support levels for indices I_1 and I_2 to reach the support level of environmental degradation. These rules are subjective. For 5 states and 2 indices there would be $5^2=25$ cases(Table 3).

Table 3 : The Fuzzy Decision Making Rules

Rule Number	Renewable resources index	Exhaustible resources index	Environmental degradation	Support degree
1	E	E	VB	1
2	E	H	VB	0.8
3	E	N	S	1
4	E	L	S	0.8
5	E	VL	A	0.8
6	H	E	VB	1
7	H	H	B	1
8	H	N	B	0.8
9	H	L	A	1
10	H	VL	S	1
11	N	E	B	1
12	N	H	B	0.8
13	N	N	A	1
14	N	L	S	0.8
15	N	VL	S	1
16	L	E	B	1
17	L	H	A	1
18	L	N	S	0.8
19	L	L	S	1
20	L	VL	VS	1
21	VL	E	A	0.8
22	VL	H	S	0.8
23	VL	N	S	1
24	VL	L	VS	0.8
25	VL	VL	VS	1

E=Excellent, H=high, N=normal, L=low, VL=very low, VB=very big, B=big, A=average, S=small, VS=very small.

This table is interpreted by the if-then logical statement. For example, the value for I1 in 1995 is supported with normal and high levels. Then by using rule number 12, the environmental degradation is big. Rule building is arbitrary. Table 2 is based on Mamdani et al. (1981) decision making role. The support degree column shows the quantification degree of environmental degradation. According to the rule number 1 support degree is 1 and degradation is very big. The final stage of analysis is derivation of numerical series for environmental degradation. It is done by assigning the arbitrary values 0, 0.25, 0.5, 0.75, 1 to levels: very small, small, average, big, and very big. Therefore, for any observation of I1 and I2 in each year, there are a maximum of two support levels. For 1995, attributed values for four different sizes are 0.201(normal) and 0.799(high) for I1 and .987(normal) and .013(excellent) for I2. Then four situations occur and Table 4 shows them. Three levels of B have come with 0.161, 0.013 and 0.799; hence by using the max operator, 0.799 is accepted.

Table 4: Results of Fuzzy Decision Rules

Row	I_1/I_2	Decision making rule (1)	Degradation level (2)	Support degree (3)	Min (I_1,I_2) (4)	(3)*(4)	Max
1	N/H	12	B	0. 8	0.201	0.161	
2	N/E	11	B	1	0.013	0.013	
3	H/H	7	B	1	0.799	0.799	0.799
4	H/E	6	V B	1	0 .013	0 .013	0 .013

Source: Authors' calculations

By assigning numbers 0, 0.25, 0.5, 0.75 and 1 to levels very small, small, average, big and very big, we have level B(with value 0.799 and weight 0.75) and level VB(with value 0.013 and weight 1).

Therefore, environmental degradation degree (EDD) for year 1995 would be:

$$\text{EDD in 1995} = \frac{0.799 * 0.75 + 0.013 * 1}{0.799 + 0.013} = 0.754$$

Similar calculations have been carried out for the rest of years. Figure 9 shows the resulting degradation trends in Iran for the study period (1959-1998).

As the trend shows during the Iran-Iraq War (1980-1988) and the oil shock periods (1973 and 1979) in which pressure on natural resources and environment is greater, the environmental degradation is high. Inversely, the lower the pressure on the natural resources is, the smaller is the degradation degree.

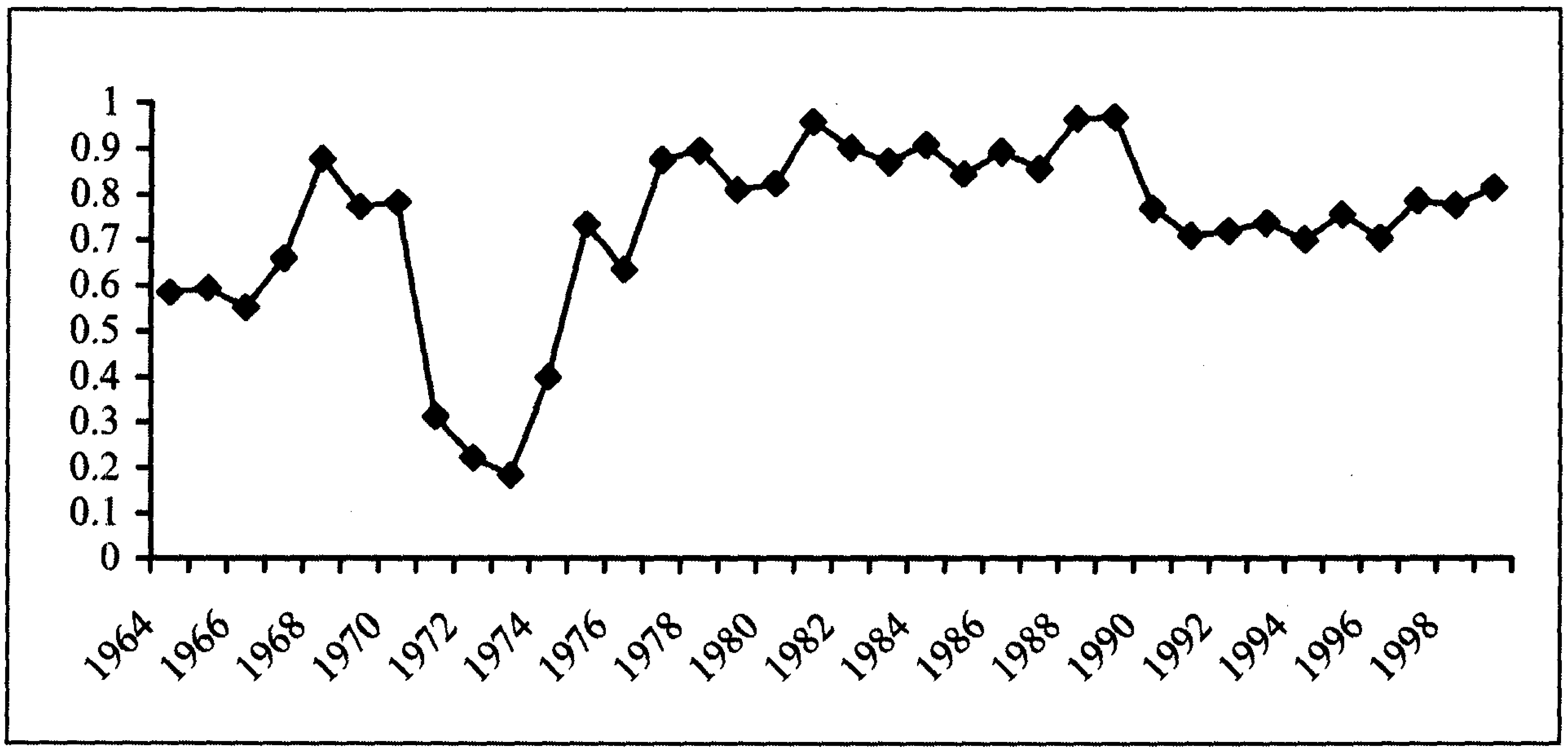

Fig 9: The Degree of Environmental Degradation in Iran

6- Conclusion

GNP in national accounts is used to measure the macroeconomic performance. This measure does not pay attention to environmental developments and pressure on natural resources resulting from economic activities. Thus, environmental degradation is not taken into consideration in the national accounts; and the importance of environment is underestimated.

Lack of environmental indices results in approaches other than econometrics and statistical analysis. The fuzzy logic method based on fuzzy sets theory, is a step towards quantifying the environment. In this method, first the indices for two groups of resources (renewable and exhaustible) are constructed based on initial studies and logical statements. Then the combination of these indices is numbered by assigning fuzzy support levels (mufti-valued functions) and fuzzy algorithm. This shows the overall state of environmental degradation. The findings of this paper show that when the pressure on natural resources and environment is high--in war and oil shocks years--environmental degradation is high. Inversely, the lower the pressure on natural resources is, the smaller is the degree of degradation. Finally, if we compute the green GNP for a particular year- or we can interpret the environmental degradation as a percent of GNP, then by scaling the fig. 9 the green GNP series will be created.

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