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Impact of Climatic and Non-climatic Factors on Sustainable Livelihood Security in Gujarat State of India: A Statistical Exploration

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Abstract

The present study estimates the district-wise sustainable livelihood security index (SLSI) in Gujarat using Composite Z-score technique during 2000-2011. It considers SLSI as an integrated index of ecological security index (ESI), economic efficiency index (EEI) and social equity index (SEI). Accordingly, it applies linear and non-linear regression models to measure the impact of different climatic factors (i.e., maximum temperature, minimum temperature and precipitation) in winter, spring, summer and autumn seasons on SLSI, ESI, EEI and SEI. It shows that SLSI, ESI, EEI and SEI are varied across districts due to high diversity in socio-economic and ecological factors, and climatic change in Gujarat. Empirical results based on linear and non-linear regression models imply that climatic factors in different weather seasons have a negative and significant impact on SLSI, ESI, EEI and SEI. So, sustainable livelihood security (SLS) would be in an alarming position due to climate change, urbanization, population growth and industrialization in Gujarat. Thus, policy makers need to adopt an effective and conducive policy to mitigate the adverse effects of those factors which have a negative impact on sustainable livelihood security. Hence, this study provides several practical and viable policy suggestions to increase the SLS in Gujarat and other Indian states.

Keywords: SLSI, ESI, EEI, SEI, Gujarat.

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Contents

1. Introduction

Over and above the economic and policy factors, and climate change will affect the sustainable livelihood security (*SLS*) of poor people due to their inadequate adaptation and lower coping capabilities in developing economies. *SLS* is a key focus area for researchers and policy makers in developing economies [1]. Also, it became a central research area for international development agencies in the 1990s [2]. *SLS* is a multi-dimensional, multi-interacting and complex phenomenon of the society [3] which varies across individual, household, region, states and country. Thus identification of *SLS* is very debatable and complex issue for researchers, international development organizations and global policy makers [4-8]. Livelihood is defined as the capability and assets which maintain and it make a better living standard of the peoples [2, 3, 9]. Livelihoods also include food system outcomes which contribute to food security and social welfare [10]. The capability of an individual comprises self-esteem, security, happiness, stress, vulnerability, power and exclusion [3, 11]. Capability approach adopted by many research organizations to assess the situation of livelihood security of peoples [12]. Livelihood assets are categorized into natural, physical, economic or financial, human and social capital [2, 3, 13-15]. Natural capital comprises soil, forest area, irrigated area, genetic resource, hydrological cycle and water resource. Cash, credit, debit, savings, basic infrastructure, physical assets, production equipment and technology are the indicators of economic or financial capital [14, 16]. Human capital comprises skills, knowledge, ability to labour, good health and physical capability [16]. Social capital includes the social network, social claims, social relationship, affiliations and association [16].

Livelihood security is a situation in which peoples are capable to overcome all stress which makes them socially and environmentally vulnerable and weak. While, *SLS* is a specific situation in which peoples are capable to mitigate the negative impact of all activities such as natural disaster, climate change, economic crisis and social conflicts [9, 10, 14]. Sustainable livelihood is a necessary condition to achieve sustainable development that includes ecological security [9]. The idea of sustainable livelihood is introduced by the Brundtland Commission on Environment and Development and United Nations Conference on Environment and Development in 1992 [16]. It provides a holistic approach for poverty eradication [14]. *SLS* includes five indicators (i.e., diversification index, food security index, input self-sufficiency, benefit-cost ratio and women's participation in agriculture) to estimate the *SLS* in India [12]. While, Böhringer and Jochem [17] observed three components (i.e. economic development, environmental development and social development) of *SLS*. *SLS* has significant interconnection with different indicators, thus, assessment of *SLS* draw the attention of policy makers, government representatives, local stakeholders and international development organizations to take precautionary action. It may be useful to adopt effective policies to maintain, regulate, utilize and conservation of natural resource (i.e., land, water and air) to mention *SLS*. Earlier studies have estimated the sustainable livelihood security index (*SLSI*) as a proxy for *SLS* in most developing economies [3-8]. However, existing researchers could not assess the influence of various socio-economic and climatic factors on *SLS* using empirical models in developing economies.

1.1. Sustainable Livelihood Security in India

In India, *SLS* is negatively influenced due to overwhelming urbanization, high population growth, extensive industrialization, reduction in arable land and forest area, degradation in groundwater availability, and climate change [18]. India could not create sustainable development path due to chronic poverty, income inequality, food insecurity, ineffective and inappropriate government policies, unfair food distribution policies, and extensive utilization of natural resource in production activities. Poverty remains a major obstacle to achieve sustainable development, socio-economic development and human development in India [13, 19]. Sustainable development meets the requirements of present population without compromising the ability of future generations to meet their own needs [20-22]. It is an integration of economic, human, social, institutional, technological and environmental development. However, most economies are not giving any attention to protecting the quality and quantity of natural factors which have a positive association with *SLS*. Hence, it is vital to maintain and protect utilization of natural resource and other environmental factors to meet the livelihood needs of coming generation [12].

In India, agricultural production activities play a significant role to provide *SLS*, employment opportunities, food security and poverty alleviation, as around 54% Indian workforce are engaged in agricultural [23-25]. In India, agricultural sector feeds vast population which stands second on the world. Thus, climate change and over-exploitation of the natural resource would bring several threats for *SLS*, poverty eradication policies, farmer's income, job opportunities, health situation and regional-development disparities across Indian states [18, 23, 25]. India has a large pool of marginal and small farmers who are financially weak, therefore year to year variability in temperature, rainfall, precipitation, soil moisture, solar radiation would bring negative implications on the livelihood of a population [18, 23]. Hence, agriculture is one of the significant factors which are positively associated livelihood security. Application of fertilizer in agriculture has created several barriers to maintain environmental sustainability, human health, food quality and loss of bio-diversity [18].

1.2. Critical Research Questions and Research Objectives

Existing studies did not estimate sustainable livelihood index (*SLSI*) for long-time data series in developing economies. Also, there is insufficient literature available which applied robust and rigorous empirical model to analyze the influence of certain climatic and socio-economic variables on constructed *SLSI*. Limited studies estimate *SLSI* for long-time data series at the district level in India [5, 8, 26]. Nevertheless, these studies did not undertake an empirical investigation to assess the association of socio-economic and climatic factors with *SLSI* in India using robust and rigorous empirical model. Hence, it is essential to identify that how variability in socio-economic variables (e.g., per capita income, urbanization, industrialization, population density, population growth, and forest area and literacy rate) and fluctuation in climatic factors (maximum and minimum temperature and precipitation) would affect the *SLS* in India. Due to existing research gap, the present study addresses the following research questions:

- What is the association of *SLS* with socio-economic and climatic factors in Gujarat?

- What is the relation of *SLS* with its components in Gujarat?
- How *SLS* gets affected due to changing in climatic factors in Gujarat?
- Which climatic and socio-economic factors have a significant influence on *SLS* in Gujarat?
- How variability in socioeconomic and climatic factors would affect *SLS* in Gujarat in near future?
- How *SLS* varies across districts in Gujarat?
- How and why *SLS* did get fluctuated during 2000-2011.

Pertinent to aforesaid research questions, the main aim of present study is to generate district-wise *SLSI* using a *Composite Z-index* technique in Gujarat. It investigates the association of *SLSI*, *ESI*, *EEI* and *SEI* with socio-economic factors using correlation coefficient analysis technique. Thereupon, it measures the influence of climatic factors on constructed *SLSI*, *ESI*, *EEI* and *SEI* using linear and non-linear regression models.

2. Socio-Economic and Geographical Structure of Gujarat

Gujarat is the industrial hub of India, and its industrial sector contributes a large share in India's gross domestic product (GDP) [27]. Despite that, health and education status of Gujarat is relatively at a lower position as compared to other states like Kerala and Tamil Nadu. Only 45% of the pregnant women in Gujarat reach the hospital at the time of delivery.[1] The maternal mortality rate is significantly higher in Gujarat as compared to Kerala and Tamil Nadu. So, primary health and education sector are in lower position in Gujarat. In Gujarat, total public expenditure on health sector has declined from 4.25% in 1990-95 to 0.77% in 2005-2010.[2] It infers that health facilities in Gujarat are not in a better position as compared to other states of India.[3] Sex ratio is a good indicator of human development and social development in an economy. The sex ratio has also declined from 920 in 2001 to 918 in Gujarat in 2011 (Census (GoI), 2011). Gujarat has around 18,539 villages, while the state has only 7,245 primary schools.[4] Thus Gujarat could not create an appropriate platform for primary education. So, Gujarat is in a poor position in social indicators, while economic growth of the state has increased due to heavy entrepreneurial activities of the people [27]. These, heavy entrepreneurial activities do have an insignificant impact on *SLS* of peoples especially in the rural area in Gujarat. So, high diversity in *SLS* across districts is a very critical issue for policy makers in Gujarat [5, 26].

3. Theoretical Outline of Sustainable Livelihood Security Index and Associated Index

Numerous studies have estimated the sustainable livelihood security index (*SLSI*) based on primary and secondary in different economies [4, 7, 17, 28-30]. Existing studies estimate the *SLSI* at the micro level (i.e., individual/household) using primary data and macro level (i.e., block/district/region/state/country) using secondary data. Many indices have been developed by the scientific research community to measure the situation of human livelihood in term of *SLSI* [4, 11] livelihood security index (*LSI*), household's livelihood security index, livelihood vulnerability index (*LVI*). Besides, scientific research community has also developed several indexes to assess the sustainable livelihood and environmental security of a region such as living planet index (*LPI*), ecological footprint (*EF*), city development index (*CDI*), human development index (*HDI*), environmental performance index (*EPI*), environmental vulnerability index (*EVI*), environmental sustainability index (*ESI*), index of sustainable economic welfare (*ISEW*), genuine progress index (*GPI*), well-being index (*WI*), genuine savings index (*GSI*), and environmental adjusted domestic product (*EDP*) [17, 20, 28-33]. These indexes integrate various components like socio-economic, demographics, livelihoods, social networks, health, food and water security and natural disaster to estimate *SLSI* [7].

Akter and Rahman [6] estimated household's livelihood security index using economic, food, nutrition, health, education, empowerment, water and sanitation indicators of human livelihood. Ajaero [3] estimates the livelihood asset index using asset indices analytical technique, and estimate the effects of livelihood asset indices on household's livelihood status in Nigeria. Kamaruddin and Samsudin [7] used sustainable livelihood analysis framework to examine the capacity and preparedness of the rural poor in receiving entrepreneurial project channeled in Malaysia. Ponnusamy and Gupta [4] developed a sustainable livelihood index (*SLI*) using seven components such as environmental conservation, permanent asset creation, food security, nutritional security, input recycling, employment generation and annual income from different enterprises. Singh and Hiremath [5] estimated the *SLSI*, which includes composite indices of ecological security index (*ESI*), economic efficiency index (*EEI*) and social equity index (*SEI*) in India. Sajjad, et al. [8] generates block-wise *SLSI* with its three composite indices, i.e. *ESI*, *EEI* and *SEI* for agricultural sustainability in Bihar (India). Ghabru, et al. [26] also estimated district-wise *SLSI* using aforesaid indicators in Gujarat.

4. Material and Research Methodology

Brief Outline of Study Area: Gujarat is one of the leading industrialized states in India. It contributes more than 7.5% to India's GDP and 18% to India's fixed capital. It occupies 10% of India's factories and its manufacturing sector contributes 28% of its state gross domestic product. It has achieved strong annual GSDP of 10% during 2005-13, which is more than the national average during the same time period. However, Gujarat is more environmentally unsustainable state of the country as compared to other Indian states. There are several problems to sustain the livelihood security of the peoples. Therefore, the present study focusses on Gujarat. This study is based on secondary data, which includes district-wise panel data during 2000-2011. For this, eighteen districts with various economic zones of Gujarat are considered in this study.

[1] http://peoplesdemocracy.in/2014/0504_pd/education-health-gujarat.
[2] http://peoplesdemocracy.in/2014/0504_pd/education-health-gujarat.
[3] http://peoplesdemocracy.in/2014/0504_pd/education-health-gujarat.
[4] http://peoplesdemocracy.in/2014/0504_pd/education-health-gujarat.

Data Sources and Description: Economic, food security, agriculture, education, women empowerment, ecological, climatic and geographical related variables at district level are taken from various sources like Centre Monitoring Indian Economy (CMIE) Pvt. Limited; Ministry of Agriculture (GoG); Census (GoI); Department of Animal Husbandry Dairying and Fisheries (GoG); Planning Commission (GoI); National Sample Survey Organization, Department of Statistics (GoI); Ministry of Statistics and Programme Implementation (GoI); Indian Meteorological Department (GoI). The SPSS, STATA, Minitab statistical software is used to construct *SLSI*, *ESI*, *EEI*, and *SEI*, and to run the proposed regression models. As some values are unavailable in time series, so interpolation and extrapolation techniques are applied to estimate the missing values to complete the time series [25, 34, 35].

4.1. Technique to Measure the Sustainable Livelihood Security Index (*SLSI*)

(i) Selection of Variables: According to literature review, the selected variables have a scientific connection with *SLS* [36]. Also, there should not be high correlation among the variables [17]. As per the literature review, livelihood security is positively and negatively associated with different indicators, therefore, it essential to segregate undertaken variables in three categories i.e. ecological security, economic efficiency and social equity [8].

(ii) Normalization or Standardization-Index of Variables: Normalization index is a technique in which a variable can be converted into one scale i.e. 0-1 [8, 15, 17, 18, 25, 26, 34, 36-41]. It makes individual variable as comparable across districts. If a variable is positively associated with *SLS*, then *standardization-index* is estimated as Ghabru, et al. [26]:

$$SI_{idt} = \{[X_{idt} - Min(X_{idt})]/[Max(X_{idt}) - Min(X_{idt})]\} \quad (1)$$

Here, *SI* is *standardization-index* or *normalization-index* for i^{th} variables; *d* is cross-sectional districts; and *t* is time. $Min(X_{idt})$ and $Max(X_{idt})$ are the minimum and maximum values respectively in an individual indicator across districts [25, 34, 39, 40]. The value of estimated *SI* lies between 0-1 for each indicator [15, 25, 37, 40-42]. If the value of an indicator (e.g., population density, population growth rate, urbanization, fertilizer consumption/hectare land, infant mortality rate) is negatively associated with *SLS* [8] then *SI* is estimated using below formula [26]:

$$SI_{idt} = \{[X_{idt} - Max(X_{idt})]/[Min(X_{idt}) - Max(X_{idt})]\} \quad (2)$$

(iii) Weight of Arbitrary Variables: Appropriate weight to each indicator make index more scientific and rational [15, 17, 18, 25, 34, 36-41]. It provides right interrelationship between variables. Weight of each indicator is examined as:

$$Wi = \{K/\surd(Var\ (SI)) \quad (3)$$

Here, W_i is estimated weight (0<W>1 and $\sum_{i=1}^{m} Wi = 1$) which is allotted to i^{th} indicator [15, 25, 37, 39-41] *Var*(*SI*) is statistical variation across *standardization-index* for all indicators [25, 34, 37, 39, 41]. In Equation (3), weight shows the reputation of an individual indicator. While, *K* is measured as:

$$\text{Here, } K = \frac{1}{\left\{\sum_{i=1}^{m}\left(\frac{1}{\sqrt{Var\ (SI)}}\right)\right\}} \quad (4)$$

(iv) Final SLSI: *SLSI* is a linear sum of all *standardization-index* that is multiplied by estimated weight of a specific indicator [17, 18, 25, 36, 37]. Mathematically, it can be specified as:

$$(SLSI)_{dt}=W_1*(SI\_1)_{dt}+W_2*(SI\_2)_{dt}+W_3*(SI\_3)_{dt}+\ldots+W_n*(SI\_n)_{dt} \quad (5)$$

Here, *SLSI* is estimated sustainable livelihood security index; W_1, W_2, W_3, …W_n are the weightages for associated variables; *SI_1*, *SI_2*, *SI_3*…*SI_n* are the *standardization-indexes* for corresponding indicators [25, 37, 39, 40].

4.2. Mathematical Functional Relationship of *SLSI* with its Associated Indicators

As per literature review, *SLS* is an integration of ecological security, economic efficiency and social equity [2, 4-8, 11, 12, 17, 26, 30]. Hence, *SLS* may be considered as a function of ecological security, economic efficiency and social equity [26]. In the present study, *SLSI* is defined as a relative index which covers most variables and provides the relative position of a specific district in sustainable livelihood security as compared to other districts. Hence, *SLSI* is a function of ecological security index (*ESI*), economic efficiency index (*EEI*) and social equity index (*SEI*). Mathematically, above-mentioned relationship may be expressed as:

$$(SLSI)_{dt} = f\{(ESI)_{dt}, (EEI)_{dt}, (SEI)_{dt}) \quad (6)$$

Here, *SLSI* is sustainable livelihood security index; *ESI*, *EEI* and *ESI* are the ecological security index, economic efficiency index and social equity index respectively; *d* is cross-sectional districts; and *t* is time period (2000-2011). These indicators can be indicated as:

$$(ESI)_{dt}=f\{(PD)_{dt}, (PGR)_{dt}, (FAGCA)_{dt}, (UR)_{dt}, (CI)_{dt}, (HHT)_{dt}) \quad (7)$$

Here, *ESI* -Ecological security index; *PD*- Population density; *PGR*- Population growth rate; *FAGCA*- Ratio of forest area with gross cropped area; *UR*- Urbanization rate; *CI*- Cropping intensity; and *HHT*- Households having toilets.

$$(EEI)_{dt}=f\{(PCAMP)_{dt}, (FGY)_{dt}, (GIAGCA)_{dt}, (FCPHL)_{dt}, (PCDDP)_{dt}, (AOPHL)_{dt}) \quad (8)$$

Here, *EEI*- Economic efficiency index; *PCAMP*- Per capita availability of milk production; *FGY*- Food-grain yield; *GIAGCA*- Ratio of gross irrigated area with gross cropped area; *FCPHL*- Fertilizer consumption/hectare land; *PCDDP*- Per capita district domestic product; and *AOPHL*- Agriculture output/hectare land.

$$(SEI)_{dt}=f\{(LR)_{dt}, (FLR)_{dt}, (HHEA)_{dt}, (PHASW)_{dt}, (IMR)_{dt}, (BR)_{dt}) \quad (9)$$

Here, *SEI*- Social equity index; *LR*- Literacy rate; *FLR*- Female literacy rate; *HHEA*- Households having electricity accessibility; *PHASW*- *Population* having accessibility to safe water; *IMR*- Infant mortality rate; and *BR*- Birth rate. *ESI*, *EEI* and *SEI* would be linear sum of *standardization-index* or *normalization-index* which is multiplied by assigned weight of associated variable that is estimated as:

$$(ESI)_{dt}=W_1*(PD\_SI)_{dt}+W_2*(PGR\_SI)_{dt}+W_3*(FAGCA\_SI)_{dt}+W_4*(UR\_SI)_{dt}+W_5*(CI\_SI)_{dt}+W_6*(HHT\_SI)_{dt} \quad (10)$$

$$(EEI)_{dt} = W_1*(PCAMP\_SI)_{dt} + W_2*(FGY\_SI)_{dt} + W_3*(GIAGCA\_SI)_{dt} + W_4*(FCPHL\_SI)_{dt} + W_5*(PCDDP\_SI)_{dt} + W_6*(AOPHL\_SI)_{dt} \quad (11)$$

$$(SEI)_{dt} = W_1*(LR\_SI)_{dt} + W_2*(FLR\_SI)_{dt} + W_3*(HHEA\_SI)_{dt} + W_4*(PHASW\_SI)_{dt} + W_5*(IMR\_SI)_{dt} + W_5*(BR\_SI)_{dt} \quad (12)$$

Here, W_1, W_2, W_3, W_4, W_5 and W_6 are the weights for related variables; *SIs* is the *standardization-index* or *normalization-index* for corresponding variables in Equation (10), (11) and (12). Final, *SLSI* would be the sum of *ESI*, *EEI* and *SEI*, which is assessed as:

$$(SLSI)_{dt} = (ESI)_{dt} + (EEI)_{dt} + (SEI)_{dt} \quad (13)$$

4.3. Justification on Variables

(a) Ecological Security Related Indicators: Ecological security is helpful to develop natural resource based economy in long-term [26]. Therefore, following variables are considered under ecological security related indicators-

1. ***Population density:*** High population density is caused to increase the additional climate vulnerability and high pressure on agricultural [8, 15, 18, 26, 34, 36, 39, 40, 43-45]. It also increases additional pressure on ecological variables. Ecological security is also negatively associated with extensive population density. So, high population density would be negatively associated with *SLS*.
2. ***Population growth rate:*** High population growth requires more natural resource to sustain basic livelihood (e.g., food, land, transport, water, air) of peoples [8, 11, 13, 15, 18, 26, 39, 40, 44, 45]. It also increases GHGs emission in the atmosphere, thus it is significant cause to increase climate change. Subsequently, high population growth is negatively associated with environmental factors and *SLS*.
3. ***Ratio of forest area with gross cropped area:*** Forest area is an important factor to absorb CO_2 emission from human and economic activities and it mitigates the negative impact of climate change in agricultural and other production activities [5, 8, 13, 15, 18, 25, 26, 35, 36, 39, 40, 43, 45]. Forest area also provides the livelihood opportunity in term of hunting, wood, timber, other [1]. Also, forest area maintains the balance in ecological variables, therefore it is a better adaptable technique to mitigate the adverse effects of climate change in production activities, and thus it is helpful to increase *SLS*. Hence, the ratio of forest area with a gross sown area is used as a proxy as a crucial indicator of ecological security in this study.
4. ***Urbanization Rate:*** The association between urbanization rate and *SLS* is complex. As urbanization is caused to increase carbon emission, therefore it is a significant contributor to increase climate change [15, 36, 40, 43-45]. Hence, *SLS* is negatively correlated with urbanization rate in those economies which are unable to maintain the quality and quantity of natural resource due to higher urbanization [25].
5. ***Cropping intensity (ratio of a gross cropped area with net sown area):*** Cropping intensity is a crucial indicator to increase the crop production [8, 15, 18, 25, 26, 36, 39, 40, 43, 45]. Thus, it useful to improve the farmer's income and their livelihood security.
6. ***Households having toilets:*** Sanitation facilities are an essential component to maintain the ecological security, thus households having toilets is considered as a proxy for sanitation facility in this study.

Table-1. Description of ecological security related indicators and sources of data

Ecological Security Related Indicators			
Indicators	**Unit**	**Symbol**	**Source**
Population density	Number	*PD*	Gujarat Social Development Infrastructure Board Society, General Administrative Department (Planning), Government of Gujarat
Population growth rate	%	*PGR*	
Ratio of forest area with gross cropped area	Number	*FAGCA*	CMIE Pvt. Limited
Urbanization	%	*UR*	http://censusindia.gov.in/
Cropping intensity (ratio of gross cropped area with net sown area)	Number	*CI*	CMIE Pvt. Limited
Households having toilets	%	*HHT*	http://censusindia.gov.in/

Source: Author's compilation based on review of literature.

(b) Economic Efficiency Related Indicators: Economic efficiency provides the appropriate way to use of the natural and human resource through the application of technological advancement [26]. Hence, following variables are compiled to estimate the *EEI*:

1. ***Per capita availability of milk production:*** Milk is useful to meets the nutritional security to peoples [26, 43]. So, it is useful to increase *SLS*.
2. ***Food-grain yield:*** Food-grain yield is useful to increase per capita availability of food-grain, thus food security and subsequently *SLS* [18, 26, 39, 40].
3. ***Ratio of a gross irrigated area with gross cropped area:*** As irrigated area has a high yielding capacity than non-irrigated area [23, 25, 26, 34, 39, 40]. Irrigated area plays a significant role to increase agricultural production and farmer's income. Irrigated area is supportive to increase the *SLS* [9, 15, 18, 25, 36].
4. ***Fertilizer consumption/Ha cropped area:*** Suggested consumption of fertilizer in cultivation is useful to increase the crop productivity and agricultural sustainability [23, 26, 39, 40]. However, extensive application of fertilizer in cultivation deteriorates agricultural production activities. In addition, abundant fertilizer application in cultivation is caused to increase CO_2 emission in the atmosphere, thus it is caused to increase high probability for climate change [25]. Hence, *SLS* may decline due to extensive fertilizer application in cultivation.
5. ***Per capita district domestic product:*** Per capita income is crucial indicator to increase the food security. Food security is a prime component of *SLS*, thus it is helpful to maintain the livelihood security [39, 40, 43, 44]. Hence, per capita district domestic product is included to capture the influence of this factor in *SLS*.

6. ***Agricultural output/hectare land:*** Agricultural output/hectare land is useful to improve the farmer's income [8]. Income of agricultural labour and landless labour also improve as agricultural output/hectare land increases. Subsequently, *SLS* would be improve as agricultural output/hectare land increases.

Table-2. Description of economic efficiency related indicators and sources of data

Economic Efficiency Related Indicators			
Indicators	**Unit**	**Symbol**	**Source**
Per capita availability of milk production	Kg/ Annum	*PCAMP*	Livestock Census, Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture, GoI
Food-grain yield	Tonne/ Ha	*FGY*	Land Use Statistics, Ministry of Agriculture, Government of India, Ministry of Agriculture, GoI
Ratio of gross irrigated area with gross cropped area	Number	*GIAGCA*	Agriculture and Co-operation Department, Government of Gujarat
Fertilizer consumption/ hectare land	Tonne/ Ha	*FCPHL*	CMIE Pvt. Limited
Per capita district domestic product	Rs	*PCDDP*	Using SDP data from States of India, CMIE
Agriculture output/ hectare land	Rs	*AOPHL*	CMIE Pvt. Limited

Source: Author's compilation based on review of literature.

(c) Social Equity Related Indicators: Social equity provides an equitable distribution of available resource, thereby present and future population can get the equal economic and social benefits from development [26]. Therefore, following variables are used to create social equity index (*SEI*):

1. ***Literacy rate:*** Literate population have more understanding to use available resources to achieve more benefits for livelihood security than the illiterate person [18, 25, 26, 36, 40, 43, 44]. So, it is a significant driver to increase *SLS* for long-term.
2. ***Female literacy rate:*** Female literacy is the critical indicator of women empowerment which ensure the contribution of women in national development [5, 8, 26]. It is also useful to increase social development, thus female literacy rate is useful to increase *SLS*.
3. ***Population having electricity:*** Availability of electricity may be useful to increase the social development [8, 26]. Consequently, *SLS* is positively and significantly associated with availability of electricity.
4. ***Population having accessibility to safe water:*** Safe water is useful to maintain the health status of peoples. So, *SLS* would be improved as availability of safe drinking water increases. In this study accessibility of safe water is used as a proxy for health indicator.
5. ***Infant mortality rate (rural + urban):*** As *SLS* is positively associated with income, health and assets [10]. Subsequently, it is also a critical indicator of social development [26, 36]. Therefore, infant mortality rate is undertaken to capture the impact of health indicator on *SLS*.
6. ***Birth rate (rural + urban):*** Birth rate is a critical indicator which is highly associated with SLS. Birth rate measures the effective position of the health sector, thus birth rate is included in this study. Ghabru, et al. [26] used a number of primary health centres to create social equity index in Gujarat (India).

Table-3. Social equity related indicators and sources of data

Social Equity Related Indicators			
Indicators	**Unit**	**Symbol**	**Source**
Literacy rate	%	*LR*	CMIE Pvt. Limited
Female literacy rate	%	*FLR*	
Households having electricity accessibility	%	*HHEA*	http://censusindia.gov.in/
Population having accessibility to safe water	%	*PHASW*	
Infant mortality rate	Number	*IMR*	Health and Family Welfare Department, Government of Gujarat
Birth rate (rural + urban)	Number	*BR*	

Source: Author's compilation based on review of literature.

(d) Climatic Factors

Average precipitation, maximum temperature and minimum temperature in winter, spring, summer and autumn seasons are used as climatic factors in this study [18, 25, 36, 38, 40, 43].

5. Origination of Empirical Models

This study assesses the impact of climatic factors on *SLS* and its associated indicators. So, *SLSI*, *ESI*, *EEI* and *SEI* are used as independent variables and regresses with climatic factors using linear and non-linear regression models. For this, the models are adopted from earlier studies which also uses estimated index as dependent variables to assess the impact of explanatory variables on it. Demeke, et al. [46] used estimated food security index (*FSI*) as a dependent variable to assess the impact of socio-economic and climatic factors on it in Ethiopia. Kumar and Sharma [47] also assess the impact of climatic and non-climatic factors on estimated *FSI* in India. Ye, et al. [48] investigate the influence of climatic factors on estimated *FSI* in different climate change scenarios in China. Belloumi [49] empirically investigate the impact of socio-economic and climatic factors on estimated *FSI* in ESA countries. Kumar, et al. [44] examine the impact of socio-economic variables on estimated global food security index across economies. Tripathi [36] assessed the influence of socio-economic variables on estimated vulnerability index in Uttar Pradesh (India). Singh [40]; Sharma and Singh [39] also assessed the influence of climatic factors on estimated *FSI* in India. Also, Singh, et al. [41] used several indexes like intellectual property awareness index, science & technological development index and socio-economic development index for empirically investigation across economies. In the present study, *SLSI*, *ESI*, *EEI* and *SEI* are considered as independent variables and recursively regressed with climatic factors using linear and non-linear regression models. For this, following empirical models are used:

$$(SLSI)_{dt} = \beta_0 + \beta_t\,(ttf) + \beta_1\,(amaxtwise)_{dt} + \beta_2\,(amaxtspse)_{dt} + \beta_3\,(amaxtsuse)_{dt} + \beta_4\,(amaxtause)_{dt} + \beta_5\,(amintwise)_{dt} + \beta_6\,(amintspse)_{dt} + \beta_7\,(amintsuse)_{dt} + \beta_8\,(amintause)_{dt} + \beta_9\,(apcpwise)_{dt} + \beta_{10}\,(apcpspse)_{dt} + \beta_{11}\,(apcpsuse)_{dt} + \beta_{12}\,(apcpause)_{dt} + U_{dt} \quad (14)$$

Here, β_0 is the constant coefficient; β_t is the regression coefficient of time trend factor; $\beta_1 \ldots \beta_{12}$ are the regression coefficients of associated climatic factors; U_{dt} is the error term; *d* is the cross-sectional districts and *t* is time period in Equation (14). The detail description of climatic factors is given in Table: 4.

Table-4. Description of climatic factors

Description of climatic factors			
Indicators	**Unit**	**Symbol**	**Sources**
Average maximum tempereture in winter season	0C	*amaxtwise*	Indian Meteorological Department (GoI); Indian Institute of Tropical Meteorology (IITM); and Geographic Information System (GIS) Software
Average maximum tempereture in spring season	0C	*amaxtspse*	
Average maximum tempereture in summer season	0C	*amaxtsuse*	
Average maximum tempereture in autumn season	0C	*amaxtause*	
Average minimum tempereture in winter season	0C	*amintwise*	
Average minimum tempereture in spring season	0C	*amintspse*	
Average minimum tempereture in summer season	0C	*amintsuse*	
Average minimum tempereture in autumn season	0C	*amintause*	
Average precipitation in winter season	mm	*apcpwise*	
Average precipitation in spring season	mm	*apcpspse*	
Average precipitation in summer season	mm	*apcpsuse*	
Average precipitation in autumn season	mm	*apcpause*	

Source: Author's compilation based on review of literature.

$$(ESI)_{dt} = \theta_0 + \theta_t\,(ttf) + \theta_1\,(amaxtwise)_{dt} + \theta_2\,(amaxtspse)_{dt} + \theta_3\,(amaxtsuse)_{dt} + \theta_4\,(amaxtause)_{dt} + \theta_5\,(amintwise)_{dt} + \theta_6\,(amintspse)_{dt} + \theta_7\,(amintsuse)_{dt} + \theta_8\,(amintause)_{dt} + \theta_9\,(apcpwise)_{dt} + \theta_{10}\,(apcpspse)_{dt} + \theta_{11}\,(apcpsuse)_{dt} + \theta_{12}\,(apcpause)_{dt} + \phi_{dt} \quad (15)$$

Here, θ_0 is constant coefficient; θ_t is the regression coefficient of time trend factor; $\theta_1 \ldots \theta_{12}$ are the regression coefficients of associated climatic factors; and ϕ_{dt} is the error term in Equation (15).

$$(EEI)_{dt} = \lambda_0 + \lambda_t (ttf) + \lambda_1\,(amaxtwise)_{dt} + \lambda_2\,(amaxtspse)_{dt} + \lambda_3\,(amaxtsuse)_{dt} + \lambda_4\,(amaxtause)_{dt} + \lambda_5\,(amintwise)_{dt} + \lambda_6\,(amintspse)_{dt} + \lambda_7\,(amintsuse)_{dt} + \lambda_8\,(amintause)_{dt} + \lambda_9\,(apcpwise)_{dt} + \lambda_{10}\,(apcpspse)_{dt} + \lambda_{11}\,(apcpsuse)_{dt} + \lambda_{12}\,(apcpause)_{dt} + €_{dt} \quad (16)$$

Here, λ_0 is constant coefficient; λ_t is the regression coefficient of time trend factor; $\lambda_1 \ldots \lambda_{12}$ are the regression coefficients of related climatic factors; and $€_{dt}$ is error term in Equation (16).

$$(SEI)_{dt} = \xi_0 + \xi_t\,(ttf) + \xi_1\,(amaxtwise)_{dt} + \xi_2\,(amaxtspse)_{dt} + \xi_3\,(amaxtsuse)_{dt} + \xi_4\,(amaxtause)_{dt} + \xi_5\,(amintwise)_{dt} + \xi_6\,(amintspse)_{dt} + \xi_7\,(amintsuse)_{dt} + \xi_8\,(amintause)_{dt} + \xi_9\,(apcpwise)_{dt} + \xi_{10}\,(apcpspse)_{dt} + \xi_{11}\,(apcpsuse)_{dt} + \xi_{12}\,(apcpause)_{dt} + \tau_{dt} \quad (17)$$

Here, ξ_0 is the constant coefficient; $\xi_1 \ldots \xi_{12}$ are the regression coefficients of associated climatic factors; and τ_{dt} is the error term in Equation (17). For non-linear regression models, the square term of all climatic factors are included in the above-mentioned Equation (14), (15), (16) and (17) which are given as:

$$(SLSI)_{dt} = \alpha_0 + \alpha_t\,(ttf) + \alpha_1\,(amaxtwise)_{dt} + \alpha_2\,(amaxtwise\text{^}2)_{dt} + \alpha_3\,(amaxtspse)_{dt} + \alpha_4\,(amaxtspse\text{^}2)_{dt} + \alpha_5\,(amaxtsuse)_{dt} + \alpha_6\,(amaxtsuse\text{^}2)_{dt} + \alpha_7\,(amaxtause)_{dt} + \alpha_8\,(amaxtause\text{^}2)_{dt} + \alpha_9\,(amintwise)_{dt} + \alpha_{10}\,(amintwise\text{^}2)_{dt} + \alpha_{11}\,(amintspse)_{dt} + \alpha_{12}\,(amintspse\text{^}2)_{dt} + \alpha_{13}\,(amintsuse)_{dt} + \alpha_{14}\,(amintsuse\text{^}2)_{dt} + \alpha_{15}\,(amintause)_{dt} + \alpha_{16}\,(amintause\text{^}2)_{dt} + \alpha_{17}\,(apcpwise)_{dt} + \alpha_{18}(apcpwise\text{^}2)_{dt} + \alpha_{19}\,(apcpspse)_{dt} + \alpha_{20}\,(apcpspse\text{^}2)_{dt} + \alpha_{21}\,(apcpsuse)_{dt} + \alpha_{22}\,(apcpsuse\text{^}2)_{dt} + \alpha_{23}\,(apcpause)_{dt} + \alpha_{24}\,(apcpause\text{^}2)_{dt} + \varpi_{dt} \quad (18)$$

Here, α_0 is the constant coefficient; α_t is the regression coefficient of time trend factors; $\alpha_1 \ldots \alpha_{24}$ are the regression coefficients of corresponding variables; and ϖ_{dt} is the error term in Equation (18).

$$(ESI)_{dt} = €_0 + €_t\,(ttf) + €_1\,(amaxtwise)_{dt} + €_2\,(amaxtwise\text{^}2)_{dt} + €_3\,(amaxtspse)_{dt} + €_4\,(amaxtspse\text{^}2)_{dt} + €_5\,(amaxtsuse)_{dt} + €_6\,(amaxtsuse\text{^}2)_{dt} + €_7\,(amaxtause)_{dt} + €_8\,(amaxtause\text{^}2)_{dt} + €_9\,(amintwise)_{dt} + €_{10}\,(amintwise\text{^}2)_{dt} + €_{11}\,(amintspse)_{dt} + €_{12}\,(amintspse\text{^}2)_{dt} + €_{13}\,(amintsuse)_{dt} + €_{14}\,(amintsuse\text{^}2)_{dt} + €_{15}\,(amintause)_{dt} + €_{16}\,(amintause\text{^}2)_{dt} + €_{17}\,(apcpwise)_{dt} + €_{18}(apcpwise\text{^}2)_{dt} + €_{19}\,(apcpspse)_{dt} + €_{20}\,(apcpspse\text{^}2)_{dt} + €_{21}\,(apcpsuse)_{dt} + €_{22}\,(apcpsuse\text{^}2)_{dt} + €_{23}\,(apcpause)_{dt} + €_{24}\,(apcpause\text{^}2)_{dt} + \varepsilon_{dt} \quad (19)$$

Here, $€_0$ is the constant coefficient; $€_t$ is the regression coefficient of time trend factors; $€_1 \ldots €_{24}$ are the regression coefficients of corresponding variables; and ε_{dt} is the error term in Equation (19).

$$(EEI)_{dt} = ¥_0 + ¥_t\,(ttf) + ¥_1\,(amaxtwise)_{dt} + ¥_2\,(amaxtwise\text{^}2)_{dt} + ¥_3\,(amaxtspse)_{dt} + ¥_4\,(amaxtspse\text{^}2)_{dt} + ¥_5\,(amaxtsuse)_{dt} + ¥_6\,(amaxtsuse\text{^}2)_{dt} + ¥_7\,(amaxtause)_{dt} + ¥_8\,(amaxtause\text{^}2)_{dt} + ¥_9\,(amintwise)_{dt} + ¥_{10}\,(amintwise\text{^}2)_{dt} + ¥_{11}\,(amintspse)_{dt} + ¥_{12}\,(amintspse\text{^}2)_{dt} + ¥_{13}\,(amintsuse)_{dt} + ¥_{14}\,(amintsuse\text{^}2)_{dt} + ¥_{15}\,(amintause)_{dt} + ¥_{16}\,(amintause\text{^}2)_{dt} + ¥_{17}\,(apcpwise)_{dt} + ¥_{18}(apcpwise\text{^}2)_{dt} + ¥_{19}\,(apcpspse)_{dt} + ¥_{20}\,(apcpspse\text{^}2)_{dt} + ¥_{21}\,(apcpsuse)_{dt} + ¥_{22}\,(apcpsuse\text{^}2)_{dt} + ¥_{23}\,(apcpause)_{dt} + ¥_{24}\,(apcpause\text{^}2)_{dt} + \mu_{dt} \quad (20)$$

Here, $¥_0$ is the constant coefficient; $¥_t$ is the regression coefficient of time trend factors; $¥_1 \ldots ¥_{24}$ are the regression coefficients of corresponding variables; and μ_{dt} is the error term in Equation (20).

$$(SEI)_{dt} = \delta_0 + \delta_t\,(ttf) + \delta_1\,(amaxtwise)_{dt} + \delta_2\,(amaxtwise\text{^}2)_{dt} + \delta_3\,(amaxtspse)_{dt} + \delta_4\,(amaxtspse\text{^}2)_{dt} + \delta_5\,(amaxtsuse)_{dt} + \delta_6\,(amaxtsuse\text{^}2)_{dt} + \delta_7\,(amaxtause)_{dt} + \delta_8\,(amaxtause\text{^}2)_{dt} + \delta_9\,(amintwise)_{dt} + \delta_{10}\,(amintwise\text{^}2)_{dt} + \delta_{11}\,(amintspse)_{dt} + \delta_{12}\,(amintspse\text{^}2)_{dt} + \delta_{13}\,(amintsuse)_{dt} + \delta_{14}\,(amintsuse\text{^}2)_{dt} + \delta_{15}\,(amintause)_{dt} + \delta_{16}\,(amintause\text{^}2)_{dt} + \delta_{17}\,(apcpwise)_{dt} + \delta_{18}(apcpwise\text{^}2)_{dt} + \delta_{19}\,(apcpspse)_{dt} + \delta_{20}\,(apcpspse\text{^}2)_{dt} + \delta_{21}\,(apcpsuse)_{dt} + \delta_{22}\,(apcpsuse\text{^}2)_{dt} + \delta_{23}\,(apcpause)_{dt} + \delta_{24}\,(apcpause\text{^}2)_{dt} + \psi_{dt} \quad (21)$$

Here, δ_0 is the constant coefficient; δ_t is the regression coefficient of time trend factors; $\delta_1 \ldots \delta_{24}$ are the regression coefficients of corresponding variables; and μ_{dt} is the error term in Equation (21).

5.1. Selection of Appropriate Empirical Model

As the sample size of this study includes 18 districts of Gujarat, which is compiled as district-wise panel data. These districts have high variation in climatic and socio-economic factors. Thus, it is essential to select an appropriate, consistent and viable empirical model to provide a viable statistical inference on empirical results. Firstly, Im-Pesaran-Shin test is applied to identify the existence of panel unit root in the individual time series. Variance inflation factor (*VIF*) is estimated to recognize the multicollinearity in explanatory variables [36]. Ramsay RESET test is considered to identify that whether functional forms of linear and linear regression models is appropriate or not. Thereafter, random effect model is used to estimate the regression coefficients of explanatory variables in all model under the assumption that variation across districts is random and independent variables do have an insignificant impact on predictors [23, 25, 34, 47]. The consistency of this model is checked through Breusch-Pagan Lagrange multiplier test [25, 34, 47]. Fixed effect model is useful to capture the variation across districts and to make results unbiased. Therefore, fixed effect model is also applied, while the appropriateness of this model is recognized through Hausman specification test [23, 25, 34, 47]. Pesaran's test is also used to identify the cross-sectional independence in panel data [23, 25, 34, 47]. The presence of group-wise heteroskedasticity is recognized using Modified Wald test [25, 34, 47]. Autocorrelation is a major problem in panel data, thus the presence of autocorrelation is identified through Wooldridge test [23, 25, 34, 47]. Finally, Prais Winsten models with panels corrected standard errors estimations (*PCSEs*) and feasible generalize least square (*FGLS*) estimations are used to estimate the regression coefficients of explanatory variables for proposed regression models. It gives preference to *PCSEs* model because this model provides better results than *FGLS* model [23, 25, 34, 47, 50].

6. Descriptive and Empirical Findings

6.1. Brief Explanation on Descriptive Results

Figure: 1 indicates the relative position of across districts in estimated *SLSI* during 2000-2011. The mean values of *SLSI* for time periods 2000-2005 and 2006-2011, implies that Bharuch, Mahesana, Amreli, Junagadh, Sabarkantha and Rajkot have *SLSI*'s more than 1.5, thus these districts have a relatively better position in *SLS* as compared to others districts in Gujarat. Kachchh, Valsad, Surendranagar, Dangs, Panchmahals and Surat have a *SLSI*'s value less than 1.40, thus districts are in relatively lower position in *SLS*. Jamnagar, Bhavnagar, Kheda, Vadodara, Ahmedabad and Banaskantha have *SLSI*'s value between 1.50- 1.40, thus these districts in middle position in estimated *SLSI*. Since the *SLSI*'s value lies between 1.88-1.17, therefore, *SLS* significantly varies across districts in Gujarat. The variation exists due to high variation in population density, population growth rate, ratio of forest area with gross cropped area, urbanization rate, cropping intensity (ratio of gross cropped area with net sown area), households having toilets, per capita availability of milk production, food-grain yield, ratio of gross irrigated area with gross cropped area, fertilizer consumption/hectare land, per capita district domestic product, agriculture output/hectare land, literacy rate, female literacy rate, households having accessibility to electricity, population having accessibility to safe water, infant mortality rate and birth rate (rural + urban) across districts in Gujarat. Also, estimated correlation coefficients of *SLSI* with socio-economic variables imply that *SLSI* is negatively associated with population density (r= -0.360), population growth rate (r= -0.56), urbanization rate (r= -0.144) and infant mortality rate (r= -0.247) (Refer to Table: C1 in Appendix: C). cropping intensity (r= 0.127), households having toilets (r= 0.161), food-grain yield (r= 0.308), ratio of gross irrigated area with gross copped area (r= 0.136), fertilizer consumption/hectare land (r= 0.045), per capita district domestic product (r= 0.388), agricultural output/hectare land (r= 0.267), literacy rate (r= 0.312), household having electricity accessibility (r= 0.271), population having accessibility of safe water (r= 0.403) and birth rate (r= 0.152) have a positive association with sustainability livelihood security in Gujarat.

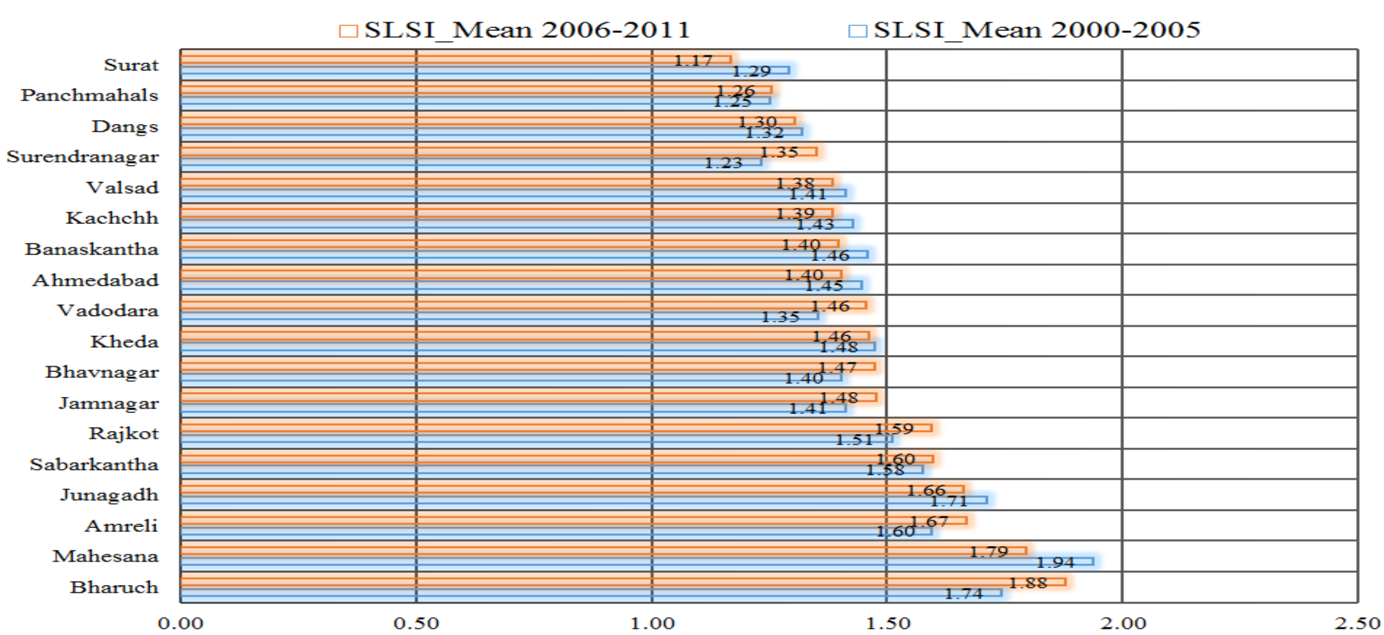

Figure-1. Estimated *SLSI* across districts in Gujarat

Source: Author's estimation.

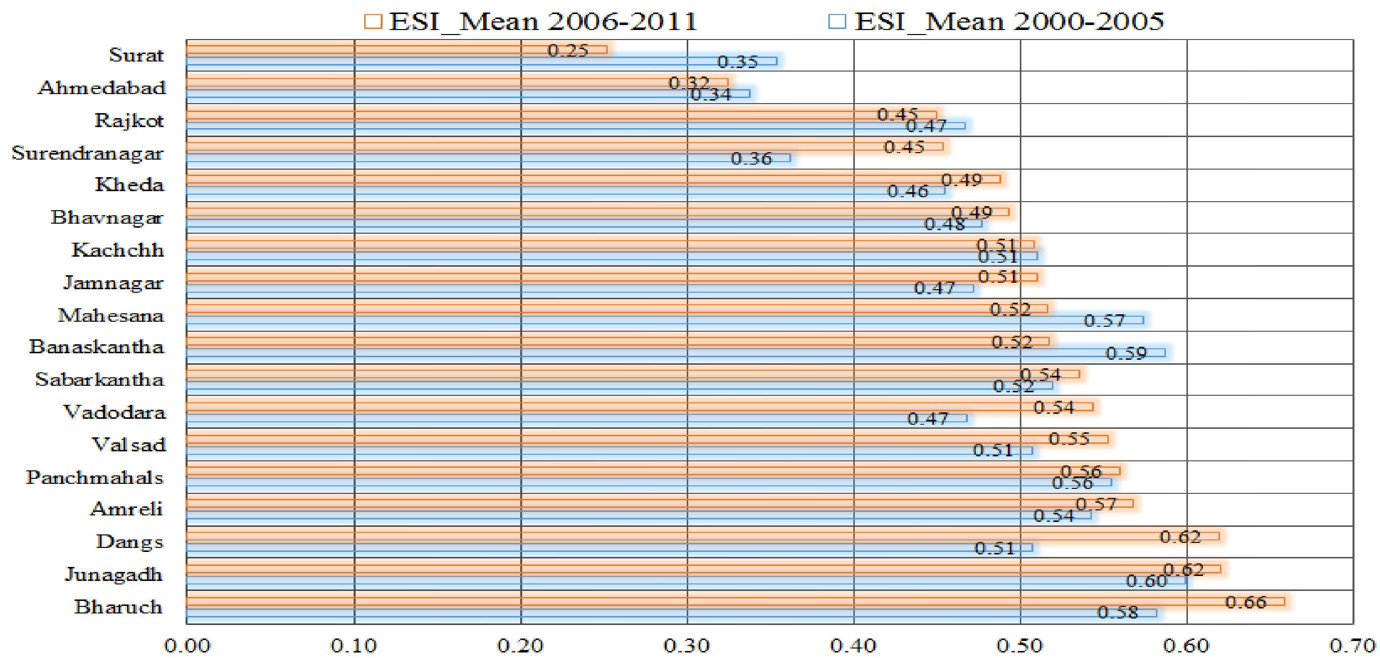

Figure-2. Estimated *ESI* across districts in Gujarat

Source: Author's estimation.

Figure: 2 provide the relative position of across districts in estimated *ESI* during 2000-2011. The estimates demonstrate that Bharuch, Junagadh, Dangs, Amreli, Panchmahal, Valsad, Vadodara, Sabarkantha, Banaskantha, Mahesana, Jamnagar and Kachchh have an *ESI*'s value more than 0.50. Thus, these districts have a better position in ecological security as compared to other districts of Gujarat. Other districts have an *ESI*'s value less than 0.50. Therefore, these districts are in a relatively poor position in the estimated value of *ESI*. A value of *ESI* lie between 0.66-0.25, thus it shows that these districts have a significant variation in ecological security due to high variation in population density, population growth rate, ratio of forest area with gross cropped area, urbanization rate, cropping intensity (ratio of gross cropped area with net sown area) and households having toilets across districts in Gujarat. Estimates based on Karl-person correlation coefficients infer that ecological security is negatively correlated with population density (r= 0.592), population growth rate (*r*= 0.491) and urbanization rate (*r*= 0.620). While, ecological security is positively associated with forest area (*r*= 0.260), cropping intensity (*r*=0.082), per capita availability of milk production (*r*= 0.288) and per capita district domestic product (*r*= 0.186) (Refer to Table: C1 in Appendix: C).

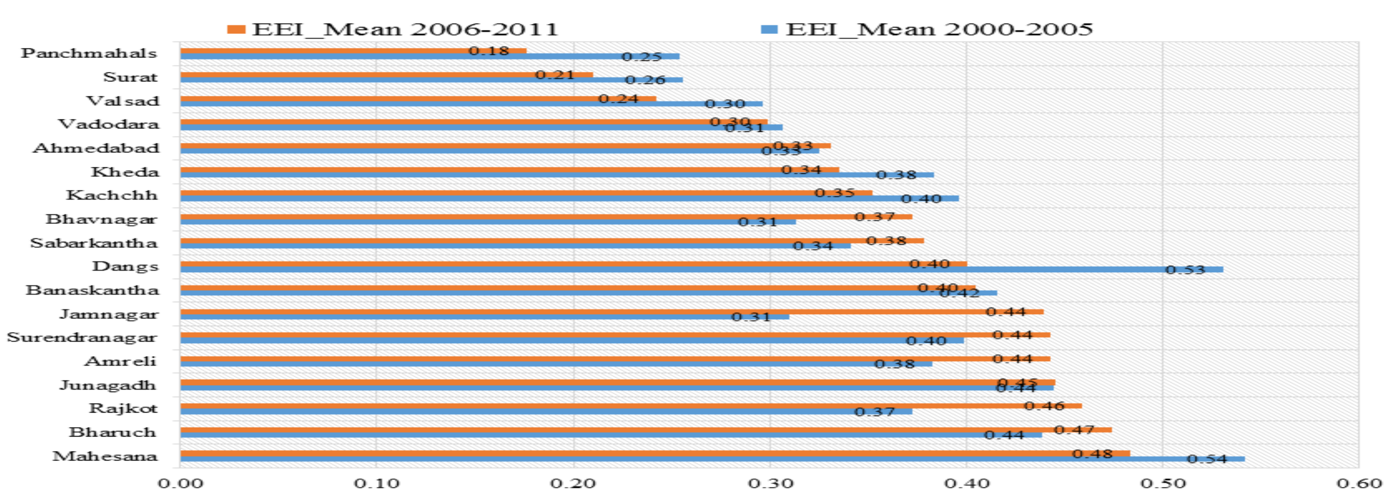

Figure-3. Estimated *EEI* across districts in Gujarat

Source: Author's estimation.

Variation in economic efficiency across districts is measured through economic efficiency index, which is given in Figure: 3. The estimated value of *EEI* is less than 0.5 across districts, thus these districts are inefficient to maintain economic efficiency. However, the values of *EEI* are lies between 0.48-0.18 during 2006-2011. Therefore, all districts have a high and significant variation in economic efficiency due to high diversity in per capita availability of milk production, food-grain yield, ratio of a gross irrigated area with gross cropped area, fertilizer consumption/hectare land, per capita district domestic product and agriculture output/hectare land across districts in Gujarat. Estimated correlation coefficients also indicate that economic efficiency is negatively associated with population density (*r*= -0.483), population growth rate (*r*= -0.362), urbanization rate (*r*= -0.287) and infant mortality rate (*r*= -0.232) (Refer to Table: C1 in Appendix: C). While, economic efficiency is positively associated with per capita availability of milk production (*r*= 0.387), food-grain yield (*r*= 0.262), ratio of gross irrigated area with gross cropped area (*r*= 0.499), per capita district domestic product (*r*= 0.499) and agricultural output per hectare land (*r*= 0.362).

The variation in social equity across districts is measured through estimation of social equity index (*SEI*) during 2000-2011, which is given in Figure: 4. The mean value of *SEI* during 2000-2005 and 2006-2011 shows that these districts have a significant variation in social equity. The estimated values of *SEI* are observed more than 0.50 during 2006-2001 for Mahesana, Ahmedabad, Bharuch, Surat, Rajkot, Sabarkantha, Amreli, Kheda, Vadodara, Bhavnagar, Junagadh, Valsad, Jamnagar, Kachchh, and Panchmahals. Also, the value of *SEI* lies between 0.79-0.28 for across districts in Gujarat. The variation in *SEI* exists due to high diversity in literacy rate, female literacy rate, households having electricity accessibility, the population having accessibility to safe water, infant mortality rate and birth rate (rural + urban) across districts in Gujarat. As estimated correlation coefficients of *SEI* with socio-economic variables demonstrates that social equity is positively associated with literacy rate (r= 0.767), female literacy rate (r= 0.700), household having electricity accessibility (r=0.651), population having accessibility of safe water (r= 0.743), infant mortality rate (r= 0.196) and birth rate (r= 0.085), food-grain yield (r= 0.174), ratio of gross irrigated area with gross cropped area (r= 0.183) and fertilizer consumption per hectare land (r= 0.211) (Refer to Table: C1 in Appendix: C). While social equity is negatively associated with population growth rate (r= -0.171).

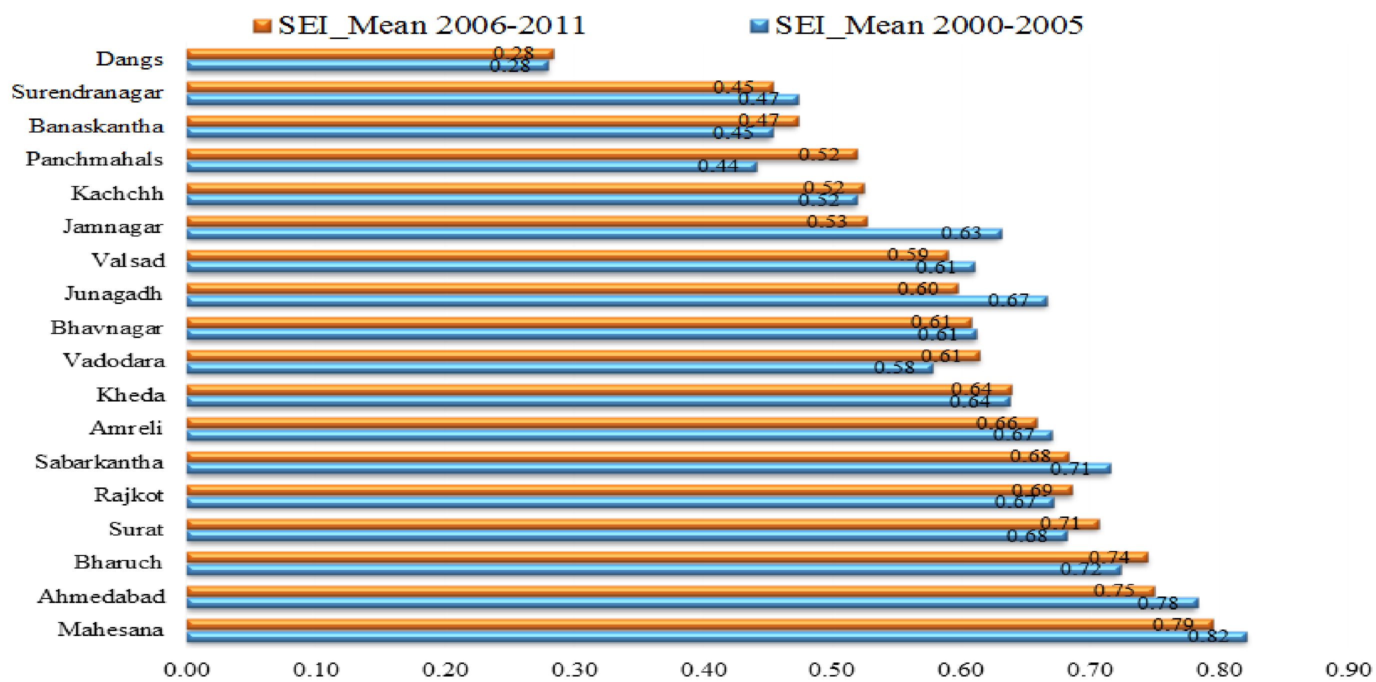

Figure-4. Estimated *SEI* across districts in Gujarat

Source: Author's estimation.

6.2. Validity and Consistency of Estimated SLSI

The present study creates district-wise *SLSI* and its associated indexes i.e. *ESI*, *EEI* and *SEI* using *Composite Z-score* technique. Therefore, it is essential to check the validity and consistency of estimated index to make the unanimity among the researchers and policy makers [25, 34, 36, 44, 47]. It also measures the accuracy and viability of estimated index. In fact, the estimated index can be used for further empirical investigation after validation. The validity of an estimated index can be checked through estimating correlation coefficients among it and its associated index [25, 36, 44, 47]. If an estimated index has a positive or negative but statistically significant association with its associated index, then it may be considered as 'good' [25, 36, 44, 47]. In order to check the validity and consistency of estimated *SLSI*, *ESI*, *EEI* and *SEI*, the Karl Pearson correlation coefficients are estimated among these indicators [25, 36, 44, 47]. The correlation coefficients among the *SLSI*, *ESI*, *EEI* and *SEI* are given in Table: 5. Estimates imply that *SLSI* is positively associated with *ESI*, *EEI* and *SEI*. Further, it infers that *SLS* would be improved with increase in ecological security, economic efficiency and social equity in Gujarat. While *ESI* is negatively associated with *SEI*, thus social equity may be declined as increase in ecological security. Economic efficiency and social equity is also negatively correlated with each other. So, it is a great concern to increase the economic efficiency and social equity in Gujarat.

Table-5. Pearson correlation coefficients among *SLSI* and its associated indexes

Parameters	SLSI	ESI	EEI	SEI
SLSI	1	0.529**	0.650**	0.576**
ESI	0.529**	1	0.259**	-0.188**
EEI	0.650**	0.259**	1	-0.002
SEI	0.576**	-0.188**	-0.002	1

Note: *SLSI*- Sustainable livelihood security index; *ESI*- Ecological security index; *EEI*- Economic efficiency index; *SEI*- Social equity index.

Source: Author's estimation; *and** shows that correlation coefficients are statistically significant at 0.05 and 0.01 significance level.

6.3. Description of Empirical Results

6.3.1. Association of *SLSI* with Climatic Factors

The association of *SLSI* with climatic factors are given in Equation (22) and (23). As *F-value under* Ramsey RESET is statistically insignificant, thus linear regression model produces better results than non-linear regression model. However, results based on non-linear regression model also provide the relationship between *SLSI* and climatic factors. Regression coefficients based on linear regression model imply that *SLS* is negatively associated with maximum and minimum temperature, and precipitation during winter, spring, summer and autumn seasons [**Note** *, ** and *** shows that regression coefficients are statistically significant at 1%, 5% and 10% significance level in Equation (22)… (29)]. Empirical results also indicate that maximum temperature during spring, summer and autumn seasons show a negative influence on *SLS*. Minimum temperature during winter and autumn seasons also has a negative association with *SLS*. Besides, regression coefficients of precipitation during spring, summer and autumn seasons appeared negative, thus these factors have a negative influence on *SLS* in Gujarat. The regression coefficient of time trend factor with *SLSI* under linear and non-linear regression model is found positive. Hence, the technological change would be helpful to increase *SLS* in Gujarat. Estimates based on non-linear regression model indicate that climatic factors have a non-linear relationship with *SLS*.

$(SLSI)_{dt}$= -10.1103 +0.0048 (*ttf*) +0.0971* $(amaxtwise)_{dt}$ -0.0515** $(amaxtspse)_{dt}$ -0.0582 $(amaxtsuse)_{dt}$ -0.0042 $(amaxtause)_{dt}$ -0.0902* $(amintwise)_{dt}$ +0.0240 $(amintspse)_{dt}$ +0.1998* $(amintsuse)_{dt}$ -0.0742* $(amintause)_{dt}$ +0.7360* $(apcpwise)_{dt}$ -0.0114 $(apcpspse)_{dt}$ -0.0052*** $(apcpsuse)_{dt}$ -0.0258 $(apcpause)_{dt}$ $+U_{dt}$ [*N*= 216; *Wald* Chi^2 =58*; *R-squared* =0.1985; *Mean VIF*= 5.77; *AIC*= -120.4305; *BIC*= -73.1766; *F-Value*(Ramsey RESET)= 0.35] (22)

$(SLSI)_{dt}$ = -3.9216 +0.0055 (*ttf*) +0.7385** $(amaxtwise)_{dt}$ -0.0096*** $(amaxtwise\text{^}2)_{dt}$ -0.6937*** $(amaxtspse)_{dt}$ +0.0084 $(amaxtspse\text{^}2)_{dt}$ +0.3273 $(amaxtsuse)_{dt}$ -0.0067 $(amaxtsuse\text{^}2)_{dt}$ -0.8773*** $(amaxtause)_{dt}$ +0.0131*** $(amaxtause\text{^}2)_{dt}$ -0.7264* $(amintwise)_{dt}$ +0.0202* $(amintwise\text{^}2)_{dt}$ +1.4593** $(amintspse)_{dt}$ -0.0280** $(amintspse\text{^}2)_{dt}$ -0.6018 $(amintsuse)_{dt}$ +0.0168 $(amintsuse\text{^}2)_{dt}$ -0.1416 $(amintause)_{dt}$ +0.0012 $(amintause\text{^}2)_{dt}$ -0.2353 $(apcpwise)_{dt}$ +1.6931 $(apcpwise\text{^}2)_{dt}$ +0.0140 $(apcpspse)_{dt}$ -0.0029*** $(apcpspse\text{^}2)_{dt}$ -0.0126 $(apcpsuse)_{dt}$ +0.0002 $(apcpsuse\text{^}2)_{dt}$ -0.0882 $(apcpause)_{dt}$ +0.0117 $(apcpause\text{^}2)_{dt}$ + ϖ_{dt} [*N*= 216; *Wald* Chi^2 = 84.05*; *R-squared* =0.2889; *Mean VIF* =2149.81; *AIC*= -122.2791; *BIC*= -34.5219; *F-Value*(Ramsey RESET)= 2.23***] (23)

6.3.2. Association of *ESI* with Climatic Factors

The empirical relationship between estimated *ESI* with climatic factors is given in Equation (24) and (25). The regression coefficients of explanatory variables are estimated through linear and non-linear regression models. As the *F-value* under Ramsay RESET test is found statistically insignificant for both the models, thus these models produce better and viable results. Estimates indicate that maximum temperature during spring and summer seasons have a negative influence on ecological security. Also, regression coefficients of minimum temperature during winter and summer seasons with *ESI* is found negative. Therefore, ecological security is negatively impacted due to change in minimum temperature in aforesaid seasons. Precipitation during spring and summer seasons also brings negative implications on ecological security. As regression coefficients of the original term of climatic factors and square term of climatic factors with *ESI* have an opposite sign. So, climatic factors have a non-linear relationship with ecological security. It also found that climatic factors have U-shape and Hilly-shape relationship with ecological security.

$(ESI)_{dt}$= 3.4819 -0.0012 (*ttf*) +0.0042 $(amaxtwise)_{dt}$ -0.0125 $(amaxtspse)_{dt}$ -0.0104 $(amaxtsuse)_{dt}$ +0.0015 $(amaxtause)_{dt}$ -0.0118 $(amintwise)_{dt}$ +0.0213 $(amintspse)_{dt}$ -0.0122 $(amintsuse)_{dt}$ +0.0015 $(amintause)_{dt}$ +0.1776* $(apcpwise)_{dt}$ -0.0104*** $(apcpspse)_{dt}$ -0.0006 $(apcpsuse)_{dt}$ +0.0556* $(apcpause)_{dt}$ + ϕ_{dt} [*N*= 216; *Wald* Chi^2 = 48.53*; *R-squared* =0.1022; *Mean VIF* = 5.77; *AIC*= -330.0421; *BIC*= -377.296; *F-Value*(Ramsey RESET)= 0.21] (24)

$(ESI)_{dt}$ = 28.9022** -0.0026 (*ttf*) +0.5457* $(amaxtwise)_{dt}$ -0.0083* $(amaxtwise\text{^}2)_{dt}$ -0.4087** $(amaxtspse)_{dt}$ 0.0053*** $(amaxtspse\text{^}2)_{dt}$ -0.3795 $(amaxtsuse)_{dt}$ +0.0055 $(amaxtsuse\text{^}2)_{dt}$ -0.3999*** $(amaxtause)_{dt}$ +0.0061*** $(amaxtause\text{^}2)_{dt}$ -0.2754* $(amintwise)_{dt}$ +0.0083* $(amintwise\text{^}2)_{dt}$ +0.2342 $(amintspse)_{dt}$ -0.0044 $(amintspse\text{^}2)_{dt}$ -1.0333** $(amintsuse)_{dt}$ +0.0212** $(amintsuse\text{^}2)_{dt}$ +0.0589 $(amintause)_{dt}$ -0.0018 $(amintause\text{^}2)_{dt}$ +0.2123 $(apcpwise)_{dt}$ -0.1447 $(apcpwise\text{^}2)_{dt}$ -0.0171*** $(apcpspse)_{dt}$ +0.0009 $(apcpspse\text{^}2)_{dt}$ -0.0095** $(apcpsuse)_{dt}$ +0.0003*** $(apcpsuse\text{^}2)_{dt}$ +0.1152** $(apcpause)_{dt}$ -0.0400 $(apcpause\text{^}2)_{dt}$ +ε_{dt} [*N*= 216; *Wald* Chi^2 = 95.81*; *R-squared* = 0.1973; *Mean VIF* = 2149.81; *AIC*= -377.4848; *BIC*= -289.7276; *F-Value*(Ramsey RESET)= 1.70] (25)

6.3.3. Association of *EEI* with Climatic Factors

The empirical association between economic efficiency index (*EEI*) and climatic factors are estimated through linear and non-linear regression models. Regression coefficients of climatic factors with *EEI* are given in Equation (26) and (27). *F-Value* under Ramsay RESET test is found statistically insignificant for the linear regression model, therefore this model produces better results than non-linear regression model. The regression coefficient of time trend factor with *EEI* is observed positive and statistically significant. It implies that adoption of technology in production activities would be helpful to increase the economic efficiency of resources. Thus, it is suggested to apply advanced technology in production activities in those districts and rural areas which are using lower technologies in production activities. Regression coefficients of maximum temperature during spring, summer and autumn seasons are found negative, thus it shows that maximum temperature during aforesaid periods would be caused to decrease economic efficiency. Minimum temperature during winter, spring and autumn seasons also have a negative influence on economic efficiency. Economic efficiency is also negatively influenced due to variability in precipitation during summer and autumn seasons. The estimates can be consistent with those studies which estimate climate change impact on the individual indicator of economic efficiency i.e. per capita availability of milk production, food-grain yield [25] ratio of gross irrigated are with a gross cropped area, per capita district domestic product, agricultural output/Ha land [50]. Estimates based on non-linear regression model provide crucial evidence that climatic factors have a non-linear relationship with economic efficiency in Gujarat.

$(EEI)_{dt}$ = -13.0881*** +0.0074*** (*ttf*) +0.0355** $(amaxtwise)_{dt}$ -0.0372* $(amaxtspse)_{dt}$ -0.0171 $(amaxtsuse)_{dt}$ -0.0122 $(amaxtause)_{dt}$ -0.0136 $(amintwise)_{dt}$ -0.0219 $(amintspse)_{dt}$ +0.0466 $(amintsuse)_{dt}$ -0.0274*** $(amintause)_{dt}$ +0.3377* $(apcpwise)_{dt}$ +0.0028 $(apcpspse)_{dt}$ -0.0062* $(apcpsuse)_{dt}$ -0.0122 $(apcpause)_{dt}$ + ϵ_{dt} [*N*= 216; *Wald* Chi^2 = 88.63*; *R-squared* = 0.2454; *Mean VIF*= 5.77; *AIC*= -418.3421; *BIC*= -371.0882; *F-Value*(Ramsey RESET)= 0.21] (26)

$(EEI)_{dt}$ = 9.8363 +0.0052 (*ttf*) +0.1606 $(amaxtwise)_{dt}$ -0.0022 $(amaxtwise\text{^}2)_{dt}$ +0.3257*** $(amaxtspse)_{dt}$ -0.0047*** $(amaxtspse\text{^}2)_{dt}$ -0.0047*** $(amaxtsuse)_{dt}$ +0.0137** $(amaxtsuse\text{^}2)_{dt}$ +0.0878 $(amaxtause)_{dt}$ -0.0016 $(amaxtause\text{^}2)_{dt}$ -0.0619 $(amintwise)_{dt}$ +0.0018 $(amintwise\text{^}2)_{dt}$ +0.2005 $(amintspse)_{dt}$ -0.0044 $(amintspse\text{^}2)_{dt}$ -1.4442* $(amintsuse)_{dt}$ +0.0297* $(amintsuse\text{^}2)_{dt}$ +0.0190 $(amintause)_{dt}$ -0.0008 $(amintause\text{^}2)_{dt}$ -0.0256 $(apcpwise)_{dt}$ +0.6172 $(apcpwise\text{^}2)_{dt}$ +0.0262** $(apcpspse)_{dt}$ -0.0026** $(apcpspse\text{^}2)_{dt}$ +0.0015 $(apcpsuse)_{dt}$ -0.0003*** $(apcpsuse\text{^}2)_{dt}$ -0.0352 $(apcpause)_{dt}$ +0.0126 $(apcpause\text{^}2)_{dt}$ +μ_{dt} [*N*= 216; *Wald* Chi^2 =193.19*; *R-squared* =0.3375; *Mean VIF* =2149.81; *AIC*= -422.4792; *BIC*= -334.722; *F-Value*(Ramsey RESET)= 2.970**] (27)

6.3.4. Association of *SEI* with Climatic Factors

The association of climatic factors with social equity index (*SEI*) is estimated through linear and non-linear regression models. The regression coefficient of climatic factors with *SEI* is presented in Equation (28) and (29). Regression coefficients of maximum temperature during spring and summer seasons has a negative and statistically significant influence on *SEI*. It means that social equity is negatively impacted due to variability in climatic factors. The influence of minimum temperature during winter and autumn seasons on *SEI* is also found negative. It infers that minimum temperature during the aforesaid periods have a negative impact on social equity. Regression coefficients of precipitation during spring and autumn seasons with *SEI* are appeared negative. Thus, social equity also negatively influenced due to change in precipitation during spring and autumn seasons. Estimates based on non-linear regression model indicates that climatic factors have a non-linear relationship. Also, climatic factors have a U-shaped and hilly-shaped relation with social equity. Since, the social equity index includes several factors i.e. literacy rate, female literacy rate, households having electricity accessibility, population having accessibility to safe water, infant mortality rate and birth rate.

$(SEI)_{dt}$ = -0.5576 -0.0013 (ttf) +0.0571* $(amaxtwise)_{dt}$ -0.0017 $(amaxtspse)_{dt}$ -0.0306*** $(amaxtsuse)_{dt}$ +0.0066 $(amaxtause)_{dt}$ -0.0647* $(amintwise)_{dt}$ +0.0245 $(amintspse)_{dt}$ +0.1652* $(amintsuse)_{dt}$ -0.0482* $(amintause)_{dt}$ +0.2211 $(apcpwise)_{dt}$ -0.0037 $(apcpspse)_{dt}$ +0.0016 $(apcpsuse)_{dt}$ -0.0691** $(apcpause)_{dt}$ $+\tau_{dt}$ [*N*= 216; *Wald Chi*^{2} = 110.73*; *R-squared* =0.3201; *Mean VIF* = 5.77; *AIC*= -326.1622; *BIC*= -278.9083; *F-Value*(Ramsey RESET)= 5.12] (28)

$(SEI)_{dt}$ = -42.6509* +0.0029 (ttf) +0.0302 $(amaxtwise)_{dt}$ +0.0009 $(amaxtwise\text{^}2)_{dt}$ -0.6089** $(amaxtspse)_{dt}$ +0.0077** $(amaxtspse\text{^}2)_{dt}$ +1.5811* $(amaxtsuse)_{dt}$ -0.0259* $(amaxtsuse\text{^}2)_{dt}$ -0.5662 $(amaxtause)_{dt}$ +0.0086 $(amaxtause\text{^}2)_{dt}$ -0.3879* $(amintwise)_{dt}$ +0.0101** $(amintwise\text{^}2)_{dt}$ +1.0255*** $(amintspse)_{dt}$ -0.0192* $(amintspse\text{^}2)_{dt}$ +1.8689* $(amintsuse)_{dt}$ -0.0341* $(amintsuse\text{^}2)_{dt}$ -0.2185** $(amintause)_{dt}$ +0.0039 $(amintause\text{^}2)_{dt}$ -0.4217 $(apcpwise)_{dt}$ +1.2210*** $(apcpwise\text{^}2)_{dt}$ +0.0049 $(apcpspse)_{dt}$ -0.0012 $(apcpspse\text{^}2)_{dt}$ -0.0046 $(apcpsuse)_{dt}$ +0.0001 $(apcpsuse\text{^}2)_{dt}$ -0.1684* $(apcpause)_{dt}$ +0.0393 $(apcpause\text{^}2)_{dt}$ + ψ_{dt} [*N*= 216; *Wald Chi*^{2} = 367.92*; *R-squared* =0.4392; *Mean VIF* = 2149.81; *AIC*= -343.7822; *BIC*= -256.0249; *F-Value*(Ramsey RESET)= 2.23***] (29)

7. Conclusion and Policy Suggestions

The main aim of this study is to estimate the district-wise sustainable livelihood security index (*SLSI*) in Gujarat using *Composite Z-score* technique during 2000-2011. For this, the study creates ecological sustainability index (*ESI*), economic efficiency index (*EEI*) and social equity index (*SEI*). *SLSI* is measured as an integrated index of *ESI*, *EEI* and *SEI* for aforesaid period. Eighteen different variables are compiled as a single number to estimate the district-wise *SLSI*. Accordingly, it used linear and non-linear regression models to examine the influence of climatic factors (i.e., maximum temperature, minimum temperature and precipitation) in winter, spring, summer and autumn seasons on *SLSI*, *ESI*, *EEI* and *SEI*.

Descriptive results indicate that there is existence high variation in sustainable livelihood security, ecological security, economic efficiency and social equity across districts in Gujarat. It is also observed that variation in *SLSI*, *ESI*, *EEI* and *SEI* exists due to the significant diversity of socio-economic and health related factors (i.e. population density, population growth rate, ratio of forest area with gross cropped area, urbanization rate, cropping intensity (ratio of gross cropped area with net sown area), households having toilets, per capita availability of milk production, food-grain yield, ratio of gross irrigated area with gross cropped area, fertilizer consumption/hectare land, per capita district domestic product, agriculture output/hectare land, literacy rate, female literacy rate, households having electricity accessibility, population having accessibility to safe water, infant mortality rate and birth rate) across districts in Gujarat. Moreover, the estimated correlation coefficients imply that *SLSI* is positively and significantly associated with *ESI*, *EEI* and *SEI*. So, it shows that *SLS* would be improved as the increase in ecological security, economic efficiency and social equity in Gujarat. Empirical results based on linear and non-linear regression models show that sustainable livelihood security, ecological security, economic efficiency and social equity are negatively associated with climatic factors during winter, spring, summer and autumn seasons. Estimates also demonstrate that sustainable livelihood security, ecological security, economic efficiency and social equity have a non-linear relationship with climatic factors. Here, it can be concluded that *SLS* would be in alarming position due to climate change in Gujarat.

As *SLSI* is negatively associated with population density, population growth rate, urbanization rate and infant mortality rate. Thus national policy maker need to adopt a policy which must reduce the negative implications of these factors on *SLS* in Gujarat. cropping intensity, households having toilets, food-grain yield, ratio of gross irrigated area with gross copped area, fertilizer consumption/hectare land, per capita district domestic product, agricultural output/hectare land, literacy rate, household having electricity accessibility, population having accessibility of safe water and birth rate have a positive association with *SLS* in Gujarat. Thus, these factors may be considered for further policy formulation. Furthermore, it is essential to control population density, population growth rate and urbanization rate in order to maintain ecological security. For this, protection of forest area, and to increase cropping intensity, per capita availability of milk production and per capita district domestic product would be helpful to sustain ecological security. It is also suggested to maintain the pace of population density, population growth and urbanization, infant mortality rate to increase economic efficiency in Gujarat. For this, increase in per capita availability of milk production, food-grain yield, ratio of gross irrigated area with gross cropped area, per capita district domestic product and agricultural output/hectare land would be imperative to improve economic efficiency in this state. Social equity would be improved as increase in literacy rate, female literacy rate, household having electricity accessibility, population having accessibility of safe water and birth rate, food-grain yield, ratio of the gross irrigated area with gross cropped area and fertilizer consumption/hectare land.

Empirical results also suggested that there is indispensable to implement the effective management policies to preserve the natural resource to maintain *SLS* in Gujarat [1]. Forest area play a significant role to maintain the ecological security, consequently forest area may be useful to conserve the other ecosystem services [31, 35, 44]. It is also desirable to apply labour-intensive and small-scale farming to contribute more to productivity and social prosperity in Gujarat. Then, it would be useful to increase *SLS* in Gujarat. There is essential to increase microirrigation facility, efficient water management policy, and adoption of advanced technologies in cultivation to maintain the *SLS* in Gujarat [26].

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Appendix: A

Table-A1. Estimated district-wise sustainable livelihood security index (*SLSI*) during 2000-2011

District	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Ahmedabad	1.515	1.520	1.373	1.379	1.447	1.436	1.501	1.374	1.337	1.386	1.463	1.362
Amreli	1.552	1.518	1.588	1.608	1.707	1.601	1.685	1.655	1.703	1.599	1.702	1.674
Banaskantha	1.449	1.490	1.390	1.487	1.535	1.393	1.295	1.389	1.356	1.427	1.502	1.405
Bharuch	1.688	1.599	1.770	1.809	1.766	1.829	2.019	1.762	1.886	1.800	1.913	1.885
Bhavnagar	1.408	1.324	1.326	1.452	1.428	1.475	1.470	1.430	1.460	1.469	1.501	1.509
Dangs	1.380	1.351	1.273	1.311	1.182	1.415	1.162	1.321	1.288	1.335	1.354	1.356
Jamnagar	1.367	1.335	1.356	1.371	1.598	1.445	1.505	1.466	1.463	1.475	1.551	1.398
Junagadh	1.650	1.677	1.692	1.679	1.853	1.714	1.633	1.648	1.617	1.705	1.770	1.607
Kachchh	1.528	1.416	1.354	1.388	1.396	1.476	1.466	1.346	1.365	1.360	1.430	1.344
Kheda	1.500	1.551	1.447	1.515	1.453	1.387	1.375	1.358	1.380	1.516	1.607	1.533
Mahesana	1.836	2.084	1.969	1.953	1.920	1.857	1.754	1.764	1.742	1.817	1.896	1.795
Panchmahals	1.322	1.256	1.308	1.263	1.198	1.155	1.208	1.190	1.213	1.245	1.352	1.327
Rajkot	1.463	1.367	1.411	1.415	1.692	1.718	1.724	1.580	1.594	1.503	1.631	1.531
Sabarkantha	1.638	1.579	1.518	1.491	1.643	1.585	1.457	1.514	1.594	1.652	1.744	1.627
Surat	1.478	1.255	1.272	1.212	1.233	1.294	1.238	1.116	1.232	1.131	1.159	1.134
Surendranagar	1.211	1.179	1.183	1.159	1.298	1.375	1.346	1.271	1.315	1.314	1.446	1.412
Vadodara	1.396	1.293	1.306	1.375	1.397	1.348	1.398	1.293	1.477	1.508	1.578	1.487
Valsad	1.579	1.471	1.382	1.394	1.349	1.305	1.465	1.324	1.359	1.378	1.300	1.481

Source: Author's estimation.

Table-A2. Estimated district-wise ecological security index (*ESI*) during 2000-2011

District	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Ahmedabad	0.435	0.404	0.297	0.311	0.301	0.277	0.282	0.296	0.296	0.360	0.363	0.350
Amreli	0.631	0.591	0.493	0.510	0.527	0.508	0.570	0.529	0.561	0.581	0.589	0.581
Banaskantha	0.623	0.622	0.563	0.621	0.612	0.485	0.445	0.498	0.481	0.588	0.569	0.528
Bharuch	0.660	0.517	0.588	0.579	0.586	0.565	0.748	0.571	0.698	0.644	0.656	0.638
Bhavnagar	0.529	0.512	0.441	0.480	0.475	0.428	0.449	0.457	0.470	0.534	0.536	0.516
Dangs	0.554	0.499	0.436	0.452	0.467	0.641	0.462	0.663	0.600	0.645	0.675	0.674
Jamnagar	0.519	0.481	0.438	0.449	0.496	0.449	0.482	0.477	0.503	0.538	0.540	0.526
Junagadh	0.641	0.606	0.577	0.569	0.646	0.560	0.527	0.605	0.582	0.690	0.680	0.643
Kachchh	0.644	0.574	0.452	0.486	0.464	0.444	0.548	0.454	0.488	0.520	0.530	0.514
Kheda	0.531	0.494	0.393	0.431	0.478	0.407	0.373	0.434	0.428	0.567	0.574	0.554
Mahesana	0.504	0.649	0.578	0.606	0.601	0.507	0.488	0.525	0.516	0.522	0.528	0.523

Panchmahals	0.587	0.586	0.622	0.517	0.524	0.495	0.543	0.503	0.486	0.602	0.614	0.614
Rajkot	0.540	0.500	0.432	0.426	0.478	0.424	0.437	0.439	0.442	0.466	0.464	0.449
Sabarkantha	0.600	0.571	0.493	0.452	0.530	0.470	0.472	0.512	0.515	0.585	0.579	0.553
Surat	0.481	0.444	0.345	0.314	0.294	0.248	0.240	0.224	0.266	0.269	0.264	0.250
Surendranagar	0.415	0.379	0.325	0.339	0.360	0.356	0.444	0.399	0.441	0.473	0.485	0.481
Vadodara	0.543	0.507	0.442	0.451	0.452	0.415	0.461	0.428	0.570	0.616	0.611	0.577
Valsad	0.583	0.525	0.494	0.483	0.498	0.461	0.576	0.477	0.494	0.577	0.595	0.600

Source: Author's estimation.

Table-A3. Estimated district-wise economic efficiency index (*EEI*) during 2000-2011

District	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Ahmedabad	0.327	0.294	0.259	0.304	0.380	0.389	0.344	0.306	0.321	0.324	0.372	0.319
Amreli	0.267	0.278	0.418	0.425	0.504	0.403	0.438	0.460	0.487	0.364	0.478	0.432
Banaskantha	0.378	0.396	0.367	0.426	0.479	0.451	0.413	0.404	0.399	0.360	0.466	0.386
Bharuch	0.332	0.356	0.458	0.508	0.453	0.525	0.501	0.457	0.460	0.417	0.509	0.501
Bhavnagar	0.289	0.211	0.309	0.372	0.348	0.349	0.373	0.364	0.394	0.346	0.367	0.391
Dangs	0.558	0.568	0.566	0.601	0.455	0.436	0.423	0.386	0.412	0.403	0.399	0.379
Jamnagar	0.256	0.210	0.275	0.286	0.465	0.367	0.408	0.445	0.452	0.438	0.527	0.368
Junagadh	0.347	0.413	0.459	0.442	0.539	0.468	0.451	0.442	0.465	0.450	0.486	0.379
Kachchh	0.368	0.370	0.383	0.406	0.436	0.416	0.338	0.356	0.370	0.339	0.408	0.301
Kheda	0.371	0.406	0.408	0.447	0.329	0.338	0.351	0.301	0.341	0.326	0.374	0.319
Mahesana	0.567	0.620	0.580	0.526	0.494	0.464	0.436	0.440	0.446	0.517	0.584	0.477
Panchmahals	0.274	0.243	0.266	0.311	0.231	0.201	0.180	0.167	0.221	0.134	0.203	0.152
Rajkot	0.262	0.196	0.339	0.352	0.574	0.516	0.501	0.445	0.500	0.394	0.507	0.408
Sabarkantha	0.354	0.279	0.300	0.324	0.392	0.400	0.388	0.337	0.391	0.356	0.438	0.363
Surat	0.356	0.140	0.272	0.234	0.267	0.265	0.226	0.195	0.293	0.185	0.208	0.154
Surendranagar	0.341	0.296	0.388	0.362	0.479	0.527	0.435	0.430	0.437	0.386	0.486	0.483
Vadodara	0.285	0.239	0.299	0.331	0.346	0.338	0.298	0.269	0.314	0.278	0.349	0.283
Valsad	0.391	0.327	0.276	0.297	0.231	0.255	0.242	0.245	0.286	0.225	0.158	0.297

Source: Author's estimation.

Table-A4. Estimated district-wise social equity index (*SEI*) during 2000-2011

District	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Ahmedabad	0.753	0.822	0.817	0.765	0.766	0.770	0.876	0.772	0.720	0.702	0.728	0.693
Amreli	0.653	0.648	0.677	0.673	0.676	0.691	0.677	0.666	0.655	0.653	0.635	0.661
Banaskantha	0.447	0.472	0.461	0.440	0.444	0.458	0.437	0.488	0.476	0.478	0.468	0.492
Bharuch	0.696	0.726	0.725	0.722	0.727	0.739	0.770	0.735	0.728	0.739	0.747	0.746
Bhavnagar	0.589	0.600	0.576	0.600	0.605	0.698	0.647	0.609	0.596	0.589	0.598	0.602
Dangs	0.269	0.284	0.271	0.258	0.260	0.338	0.278	0.272	0.277	0.287	0.281	0.303
Jamnagar	0.592	0.643	0.644	0.637	0.637	0.629	0.616	0.545	0.508	0.499	0.485	0.504
Junagadh	0.662	0.658	0.656	0.667	0.667	0.686	0.655	0.601	0.569	0.565	0.604	0.585
Kachchh	0.516	0.473	0.519	0.495	0.497	0.616	0.580	0.536	0.507	0.501	0.492	0.528
Kheda	0.598	0.651	0.647	0.637	0.646	0.642	0.651	0.624	0.610	0.623	0.659	0.660
Mahesana	0.765	0.815	0.812	0.821	0.825	0.886	0.830	0.799	0.779	0.779	0.785	0.794
Panchmahals	0.461	0.427	0.420	0.435	0.443	0.459	0.486	0.520	0.506	0.509	0.535	0.561
Rajkot	0.661	0.671	0.640	0.636	0.640	0.778	0.786	0.696	0.652	0.644	0.660	0.674
Sabarkantha	0.684	0.728	0.725	0.715	0.720	0.715	0.597	0.665	0.687	0.711	0.727	0.711
Surat	0.642	0.671	0.655	0.663	0.672	0.781	0.772	0.697	0.673	0.677	0.687	0.730
Surendranagar	0.455	0.503	0.470	0.457	0.459	0.492	0.466	0.441	0.437	0.455	0.474	0.448
Vadodara	0.568	0.547	0.566	0.593	0.598	0.595	0.638	0.596	0.593	0.614	0.618	0.626
Valsad	0.606	0.618	0.612	0.614	0.620	0.590	0.647	0.602	0.579	0.576	0.547	0.583

Source: Author's estimation.

Appendix: B

Table-B1. Association of *SLSI, ESI, EEI* and *SEI* with climatic factors

Factors	SLSI	ESI	EEI	SEI	maxtwise	maxtspse	maxtsuse	maxtause
SLSI	1	0.529**	0.650**	0.576**	-0.115	-0.037	0.011	-0.029
ESI	0.529**	1	0.259**	-0.188**	-0.081	-0.113	-0.122	-0.073
EEI	0.650**	0.259**	1	-0.002	-0.248**	-0.238**	-0.132	-0.210**
SEI	0.576**	-0.188**	-0.002	1	0.082	0.216**	0.212**	0.176**
maxtwise	-0.115	-0.081	-0.248**	0.082	1	0.439**	0.311**	0.440**
maxtspse	-0.037	-0.113	-0.238**	0.216**	0.439**	1	0.341**	-0.064
maxtsuse	0.011	-0.122	-0.132	0.212**	0.311**	0.341**	1	0.324**
maxtause	-0.029	-0.073	-0.210**	0.176**	0.440**	-0.064	0.324**	1
mintwise	-0.124	-0.037	-0.129	-0.057	0.591**	-0.213**	-0.013	0.345**
mintspse	0.011	0.024	-0.192**	0.145*	0.333**	-0.058	-0.015	0.316**
mintsuse	0.076	-0.026	-0.036	0.160*	0.140*	-0.412**	0.065	0.343**
mintause	-0.023	0.053	-0.068	-0.024	0.253**	-0.508**	-0.218**	0.382**
pcpwise	0.220**	0.111	0.235**	0.061	-0.089	0.025	-0.047	-0.074
pcpspse	-0.138*	-0.170*	-0.07	-0.02	0.260**	0.038	0.044	0.306**
pcpause	-0.165*	-0.041	-0.206**	-0.056	0.551**	0.200**	-0.207**	0.022
pcpause	-0.160*	0.142*	-0.091	-0.278**	0.413**	0.065	0.019	-0.124

Source: Author's estimation. *and** shows that correlation coefficients are statistically significant at 0.05 and 0.01 significance level.

Table-B1. Association of *SLSI, ESI, EEI* and *SEI* with climatic factors Conti…

Factors	mintwise	mintspse	mintsuse	mintause	pcpwise	pcpspse	pcpause	pcpause
SLSI	-0.124	0.011	0.076	-0.023	0.220**	-0.138*	-0.165*	-0.160*
ESI	-0.037	0.024	-0.026	0.053	0.111	-0.170*	-0.041	0.142*
EEI	-0.129	-0.192**	-0.036	-0.068	0.235**	-0.07	-0.206**	-0.091
SEI	-0.057	0.145*	0.160*	-0.024	0.061	-0.02	-0.056	-0.278**
maxtwise	0.591**	0.333**	0.140*	0.253**	-0.089	0.260**	0.551**	0.413**
maxtspse	-0.213**	-0.058	-0.412**	-0.508**	0.025	0.038	0.200**	0.065
maxtsuse	-0.013	-0.015	0.065	-0.218**	-0.047	0.044	-0.207**	0.019
maxtause	0.345**	0.316**	0.343**	0.382**	-0.074	0.306**	0.022	-0.124
mintwise	1	0.698**	0.729**	0.777**	-0.149*	0.149*	0.391**	0.333**
mintspse	0.698**	1	0.779**	0.758**	-0.176**	-0.132	0.123	0.129
mintsuse	0.729**	0.779**	1	0.856**	-0.184**	-0.091	0.009	-0.021
mintause	0.777**	0.758**	0.856**	1	-0.179**	-0.083	0.173*	0.149*
pcpwise	-0.149*	-0.176**	-0.184**	-0.179**	1	0.057	-0.059	-0.004
pcpspse	0.149*	-0.132	-0.091	-0.083	0.057	1	0.308**	0.017
pcpause	0.391**	0.123	0.009	0.173*	-0.059	0.308**	1	0.419**
pcpause	0.333**	0.129	-0.021	0.149*	-0.004	0.017	0.419**	1

Source: Author's estimation. *and** shows that correlation coefficients are statistically significant at 0.05 and 0.01 significance level.

Appendix: C

Table-C1. Association of *SLSI, ESI, EEI* and *SEI* with socio-economics factors

Factors	SLSI	ESI	EEI	SEI	PD	PGR	FAGCA	UR	CI	HHT	PCAMP
SLSI	1	0.529**	0.650**	0.576**	-0.360**	-0.559**	-0.229**	-0.144*	0.127	0.161*	-0.014
ESI	0.529**	1	0.259**	-0.188**	-0.592**	-0.491**	0.260**	-0.620**	0.082	-0.408**	0.288**
EEI	0.650**	0.259**	1	-0.002	-0.483**	-0.362**	-0.296**	-0.287**	0.082	-0.097	0.387**
SEI	0.576**	-0.188**	-0.002	1	0.294**	-0.171*	-0.313**	0.485**	0.062	0.628**	-0.538**
PD	-0.360**	-0.592**	-0.483**	0.294**	1	0.235**	0.052	0.502**	-0.011	0.394**	-0.364**
PGR	-0.559**	-0.491**	-0.362**	-0.171*	0.235**	1	0.340**	0.391**	-0.002	0.192**	-0.036
FAGCA	-0.229**	0.260**	-0.296**	-0.313**	0.052	0.340**	1	-0.260**	0.105	-0.239**	0.147*
UR	-0.144*	-0.620**	-0.287**	0.485**	0.502**	0.391**	-0.260**	1	-0.016	0.895**	-0.601**
CI	0.127	0.082	0.082	0.062	-0.011	-0.002	0.105	-0.016	1	0.005	-0.074
HHT	0.161*	-0.408**	-0.097	0.628**	0.394**	0.192**	-0.239**	0.895**	0.005	1	-0.557**
PCAMP	-0.014	0.288**	0.387**	-0.538**	-0.364**	-0.036	0.147*	-0.601**	-0.074	-0.557**	1
FGY	0.308**	0.106	0.262**	0.174*	-0.052	-0.100	-0.019	0.156*	-0.032	0.313**	-0.105
GIAGCA	0.136*	-0.057	0.081	0.183**	0.082	0.044	-0.072	0.071	0.476**	0.08	-0.105
FCPHL	0.045	-0.134*	-0.054	0.211**	0.201**	0.093	-0.003	0.156*	0.414**	0.149*	-0.166*
PCDDP	0.383**	0.186**	0.499**	0.041	-0.182**	-0.279**	-0.220**	-0.03	-0.013	0.174*	0.037
AOPHL	0.267**	0.031	0.362**	0.093	-0.100	-0.220**	-0.252**	0.032	0.411**	0.087	-0.038
LR	0.312**	-0.321**	-0.073	0.767**	0.511**	-0.057	-0.237**	0.657**	0.009	0.717**	-0.399**
FLR	0.291**	-0.294**	-0.054	0.700**	0.470**	-0.026	-0.181**	0.695**	0.011	0.789**	-0.348**
HHEA	0.271**	-0.240**	-0.084	0.651**	0.246**	-0.127	-0.244**	0.643**	0.009	0.752**	-0.646**
PHASW	0.403**	-0.221**	0.033	0.743**	0.236**	0.015	-0.372**	0.540**	0.008	0.703**	-0.442**
IMR	-0.247**	-0.497**	-0.232**	0.196**	0.412**	0.276**	-0.185**	0.715**	0.009	0.597**	-0.513**
BR	0.152*	0.267**	-0.086	0.085	-0.160*	-0.155*	0.003	-0.346**	-0.077	-0.294**	0.026

Source: Author's estimation. *and** shows that correlation coefficients are statistically significant at 0.05 and 0.01 significance level.

Table-C1. Association of *SLSI, ESI, EEI* and *SEI* with socio-economics factors Conti…

Factors	*FGY*	*GIAGCA*	*FCPHL*	*PCDDP*	*AOPHL*	*LR*	*FLR*	*HHEA*	*PHASW*	*IMR*	*BR*
SLSI	0.308**	0.136*	0.045	0.383**	0.267**	0.312**	0.291**	0.271**	0.403**	-0.247**	0.152*
ESI	0.106	-0.057	-0.134*	0.186**	0.031	-0.321**	-0.294**	-0.240**	-0.221**	-0.497**	0.267**
EEI	0.262**	0.081	-0.054	0.499**	0.362**	-0.073	-0.054	-0.084	0.033	-0.232**	-0.086
SEI	0.174*	0.183**	0.211**	0.041	0.093	0.767**	0.700**	0.651**	0.743**	0.196**	0.085
PD	-0.052	0.082	0.201**	-0.182**	-0.100	0.511**	0.470**	0.246**	0.236**	0.412**	-0.160*
PGR	-0.1	0.044	0.093	-0.279**	-0.220**	-0.057	-0.026	-0.127	0.015	0.276**	-0.155*
FAGCA	-0.019	-0.072	-0.003	-0.220**	-0.252**	-0.237**	-0.181**	-0.244**	-0.372**	-0.185**	0.003
UR	0.156*	0.071	0.156*	-0.03	0.032	0.657**	0.695**	0.643**	0.540**	0.715**	-0.346**
CI	-0.032	0.476**	0.414**	-0.013	0.411**	0.009	0.011	0.009	0.008	0.009	-0.077
HHT	0.313**	0.08	0.149*	0.174*	0.087	0.717**	0.789**	0.752**	0.703**	0.597**	-0.294**
PCAMP	-0.105	-0.105	-0.166*	0.037	-0.038	-0.399**	-0.348**	-0.646**	-0.442**	-0.513**	0.026
FGY	1	-0.05	0.008	0.417**	0.072	0.164*	0.257**	0.367**	0.210**	0.108	-0.075
GIAGCA	-0.05	1	0.870**	-0.098	0.642**	0.144*	0.101	0.035	0.237**	0.088	0.054
FCPHL	0.008	0.870**	1	-0.072	0.583**	0.230**	0.204**	0.13	0.219**	0.137*	0.024
PCDDP	0.417**	-0.098	-0.072	1	0.135*	0.053	0.145*	0.177**	0.156*	-0.077	-0.041
AOPHL	0.072	0.642**	0.583**	0.135*	1	0.067	0.071	0.165*	0.126	0.021	0.035
LR	0.164*	0.144*	0.230**	0.053	0.067	1	0.970**	0.532**	0.584**	0.457**	-0.341**
FLR	0.257**	0.101	0.204**	0.145*	0.071	0.970**	1	0.588**	0.585**	0.469**	-0.390**
HHEA	0.367**	0.035	0.13	0.177**	0.165*	0.532**	0.588**	1	0.515**	0.412**	-0.038
PHASW	0.210**	0.237**	0.219**	0.156*	0.126	0.584**	0.585**	0.515**	1	0.394**	0.104
IMR	0.108	0.088	0.137*	-0.077	0.021	0.457**	0.469**	0.412**	0.394**	1	-0.332**
BR	-0.075	0.054	0.024	-0.041	0.035	-0.341**	-0.390**	-0.038	0.104	-0.332**	1

Source: Author's estimation. *and** shows that correlation coefficients are statistically significant at 0.05 and 0.01 significance level.