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MODELING INDIAN MONSOON (RAINFALL) VOLATILITY AS AN INDEX BASED RISK TRANSFER PRODUCT

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ABSTRACT
Various research studies are now focusing on the need for exploring the potential of rainfall indexation to engage capital markets for absorbing rainfall shocks. In this paper an attempt is made to develop a general framework for conceptualizing rainfall-index based risk transfer product based on the rainfall data of select 3 out of 36 meteorological subdivisions of India. A unique rainfall index with ticker symbol Monsoon Outcome Index (MOX) for each of the major meteorological subdivision of India is proposed, along with an estimating model. Essential statistical properties of MOX series across time and subdivisions are captured which only reinforce the vast scope for launching new breed of risk market instruments.

KEYWORDS
Coefficient of variation, Monsoon Outcome Index (MOX), Rainfall Index, Volatility, Weather derivative.

INTRODUCTION
India has always been a land of extreme diversity – be it culture, landscape or weather. Of these, the weather factor presents formidable challenges since it is not possible to control. At the same, it holds the key to economic well-being of at least 60 percent of the population, which depends upon agriculture directly or indirectly.

In many parts of India irrigation is still a dream because 60 percent of the sown area depends on rainfall and at least 50 percent of the variability in crop yields is caused by rainfall variations. As such, the failure of the monsoon is the single largest reason for crop failure, leading to social turmoil in several states where indebted farmers are driven to despair.

Farmers face basically two types of risk – (1) Price risk caused by glut in the market and (2) volumetric risk caused by vagaries of weather leading to crop failure. Price risk can be hedged by use of commodity hedging futures. Volumetric risk requires weather insurance and weather derivatives.

Agricultural insurance is an industry that is still in its evolution stages in this country. Rainfall index (RI) insurance introduced by leading insurance companies in India in the recent past holds better prospects over traditional crop insurance. The development of RI insurance just marks the beginning of a journey towards creation of full-fledged weather markets for absorbing monsoon risk to meet the needs of a wide range of entities including Agri-finance, Commodity trading, hydro-power, agro processing etc. It is necessary for the insurance market to be integrated with the capital market at the earliest. Countries like Morocco (Skees,et al,2001), India(Sinha,2004),South Africa(Geyser,2004) and others have already started experimenting with rainfall derivatives, though the contracts strictly do not resemble the true nature of derivative structure. Monsoon derivative market is critical for the development of insurance market as it provides opportunities to insurers to hedge their monsoon exposure (kotreshwar, et al(2006).

INDEX-BASED RAINFALL INSURANCE
Rainfall index as a basis for insurance is superior to traditional crop insurance in several ways. Unlike crop insurance, there is no need to submit a claim and demonstrate loss to receive a payout, payment is automatic. Besides, it overcomes the problems of traditional crop insurance such as moral hazard and adverse selection.

Academic research focuses on the design of generic applicable of rainfall index to the Agri-sector. Pilot rainfall-index insurance projects have been designed and implemented by National Agricultural Insurance Corporation (NAIC), ICICI-Lombard and others since 2005.

There has been a dramatic increase in investments related to rainfall index-based insurance programmes with the involvement of international institutions like World Bank, International Finance Corporation, Asian Development Bank, World Food Programme and others. The pilot project based studies are aimed at sustainable and standardized project deployment creating new risk markets.

Various studies, including Skees et al(1999),(2001),Miranda(1991), Martin et al.(2001), (2010), Mahul (2000), and Veeramani et al(2005), have been carried out to analyse whether rainfall-index based insurance products can be an economically viable replacement for the current insurance programmes in stabilizing the revenue risk faced by the farmers. Veeramani et al(2005) have further explored the scope for the insurers' and reinsurers' participation in the insurance schemes.

The general methodology for determining indemnity and premium rate suggested in these studies incorporate the loading feature to cover losses due to unforeseen events or to build cash reserves to cover the monitoring cost (Skees et al.2001).

Payment Percentage (For drought)	=	{Strike Rain – Actual Rain}*100/ (Strike Rain)	………………….Eq (1)
Payment Percentage (For Floods)	=	{Actual Rain – Upper strike Rain}*100/ (Actual Rain	………………….Eq (2)
Indemnity	=	(payment percentage)x (liability)	………………….Eq (3)
Premium Rate	=	(Average Indemnity/Average Liability) x Loading	………………….Eq (4)

Here loading is the hiking in the premium to cover losses due to unforeseen events or to build cash reserve or to cover monitory cost.

The idea of using climatic events for insurance payments is not new, trading based on Heating Degree Days (HDDs) and Cooling Degree Days (CDDs) are available for quite some time Turvey (2001). Veeramani (2005) considers both the upper and lower bound risk, the payoff function for the call and put options are slightly modified from the function used by Turvey (1999).

$$\text{Payoff (Call)} = \begin{cases} 0, & \text{if } X \le \text{strike} \\ X - \text{Strike}, & \text{if Strike} < X < L1 \\ L1 - \text{Strike}, & \text{if } X \ge L1 \end{cases} \times \lambda \quad \text{.......................Eq(5)}$$

$$\text{Payoff (Put)} = \begin{cases} L2 - \text{Strike}, & \text{if } X \le L2 \\ \text{Strike} - X, & \text{if strike} \ge X > L2 \\ 0, & \text{if } X > \text{Strike} \end{cases} \times \lambda \quad \text{.......................Eq(6)}$$

Where, L2 and L1 are the lower and upper limits, respectively, strike is a choice variable, X is the actual value, and λ is the predetermined monetary value of an index. Veeramani et al. (2005) have concluded that there exist a vast untapped potential for rainfall options and should help developing countries like India to explore expanding markets for risk sharing.

DEVELOPING RAINFALL INDEX

Rainfall index indicates what percentage of cumulative normal expected rainfall is realized ? A higher index would mean that, compared to the cumulative long period average rainfall up to the date of index, there has been more rainfall.

National Commodities Exchange (NCDEX) pioneered the introduction of rainfall index in India. Rainfall Index for Mumbai was launched on June 01, 2005. Index for Belgaum, Erode, Guntur, Karimnagar, Ganganagar, Kottayam, Murshidabad, Rajkot and Ujjain launched on June 01, 2006. The index has been based on long period average, normal, expected rainfall. It indicates what percentage of cumulative normal expected rainfall is realized. A higher index would mean that, compared to the cumulative long period average rainfall upto the date of index, there has been more rainfall. The methodology adopted by NCDEX for calculated rainfall index may be summed up by an example:

Based on historical data, normal expected rain by June 02, 2005:28.6 mm

Actual rain by June 02, 2005 : 0.65 mm

Rainfall index (scaled by 1000) on June 03, 2005 : (0.65/28.6) x 1000 = 22.7

It has rained 2.27 pc of normal rain by June 02, 2005.

The farmer would be typically seller of the index at the start of the monsoon, and will buy it back at the end of the monsoon. A monsoon failure will imply a lower index and lower monetary value. The index thus bought back by the farmer will compensate the loss suffered on the output front.

NCDEX rainfall indices are only for purpose of display and dissemination of information, emphasizing the importance of weather trading platform for the country. Yet regulators of Indian Commodity Exchanges have not come forwarded with mechanism that would help farmers hedge against weather. Parliament yet to clear amendments to Forward Contract Regulations Act, as of now Indian regulation does not define weather as a commodity, thus impeding trading.

The rainfall indexation discussed in this paper is different in the perspective of development of risk transfer products meant for capital market. It is proposed to recognize the index using a ticker symbol, MOX (Monsoon Outcome Index), which would form the basis of rainfall derivatives.

$MOX = \Sigma R_{it}/\Sigma R_{ct} \times 1000$ ....Eq (7)

Where R_{it} represents cumulative rainfall for end of i^{th} month of the t^{th} season; R_{ct} stands for historical average cumulative monthly rainfall for the t^{th} season; and 1000 is the multiplier value where rainfall is measured equivalent to 1/1000th of a meter, i.e., in millimeters.

The computation of MOX values for each of the major selected meteorological subdivision in place of few selected city/locations is preferable mainly for two reasons:

The index becomes broad-based which in turn should facilitate the launch of a trading mechanism at the national level to meet the diverse needs, i.e., speculation, risk hedging and arbitraging.

Simultaneously, a broad-based index minimizes the impact of basis risk which looms large in any weather-based risk transfer product.

Accordingly, the MOX values have been computed for the selected 3 out of 36 meteorological subdivisions of India, summarized in Table 1. The selected meteorological subdivisions are Assam Meghalaya (ASMEG), Saurastra Katch & Diu (SAUKU) and Madhya Maharashtra (MADMH). The graph of the MOX values for one of the sub division, Assam Meghalaya for all the monsoon months is provided in Graph 1(a,b,c,d).

The required rainfall data is sourced from the Indian Institute of Tropical Meteorology (IITM) website, for South-West monsoon season starting from 1st June and ending on 30th September and the MOX values for end of each month are computed for 30 years for these select 3 subdivision, R_{ct}, value is based on the 30 years moving average cumulative rainfall for the monsoon months. It can be observed that MOX value has taken a wide range both across years and subdivisions. For instance, the MOX value for the end of Jun month for Saurastra Katch and Diu (SAUKU) sub division it varied between a minimum of 48 in the year 1982 and a maximum of 2562 in the year 1982.

MODELING THE INDEX TO ENABLE ESTIMATION

To enable determination of expected MOX value at the end of the monsoon month for each of the selected subdivisions, it is attempted to approach the linear regression method. For this purpose, the following simple linear regression equation is considered.

$T_t = b_o + b_1 * t$ ....Eq (8)

Where b_o is the Y-Coordinate intercept and b_1 is the slope. These regression coefficients are used to construct an ordinary least square Equation. SPSS is used to compute the values of b_0 and b_1 from the available values of MOX for the monsoon months.

The regression analysis is done for Sept MOX values which shows the existence of significant trend (positive) for Assam and Meghalaya (ASMEG) and the regression Equation will be $T_t = 1067 - 7.52 * t$, where t is the yearly sequence number. For other 2 subdivisions, the existence of significant trend (negative) for Sept MOX values is seen. The results of the regression estimation for September MOX values are presented in Box 1. The graph for the trend for select 3 sub divisions is depicted in graph 2 (a, b &C).

BOX 1: REGRESSION COEFFICIENT VALUES FOR SEPT MOX VALUES FOR SAMPLE SUBDIVISIONS

Subdivisions	b_o	b_1
Assam and Meghalaya (ASMEG)	1067	-7.52
Saurashtra, Kutch & Diu (SAUKU)	612	28.99
Madhya Maharashtra (MADMH)	876	9.35

Source: IITM rainfall data

ANALYSIS OF STATISTICAL PROPERTIES OF RAINFAL INDEX

Table 2 presents few statistics including Coefficient of variation for the MOX values for each of four monsoon months from 1982 to 2011 for the sample subdivisions.

The Coefficient of variation value for June is highest for all the subdivisions and varied from 21.07% to 76.86%. It decreases in the subsequent months and is lowest for September month. It implies that the MOX values revert back to the long time average rainfall at the end of monsoon period. For the end of September month MOX values, Coefficient of variation varied from 16.29% to 43.78%, indicates the existence of variations in the MOX values for rainfall amongst the sub-divisions.

To elaborate on inter-divisional independence in MOX values of rainfall data, correlation analysis amongst these three sample sub-divisions has been carried out at Table 3. Geographically adjacent sub-division's has moderate correlation where as distant sub-division's have weak to very weak (negative) correlation. Even within same sub division, MOX values for monsoon months have variable correlation and will reduce as the months are apart. Such weak correlation favours the introduction of derivative instruments for mitigating rainfall risk.

POTENTIAL APPLICATIONS OF MOX

Volatility is the basis for index trading. Most index trades relay heavily on volatility information. For this reason the proposed MOX, if launched on an exchange can be a popular trading tool.

An analysis of statistical properties of MOX implies that MOX can be a potential tool for both hedging and speculation. It may also be an excellent instrument in the quest for portfolio diversification. Diversification which most people consider a good thing is useful only if the instruments used are not correlated. One interesting feature of MOX is its relative inter-divisional independence, as the correlation between geographically distant subdivisions found to be close to zero. This makes it an excellent diversification tool and could be better for monsoon disaster hedging.

MOX would be an excellent speculation instrument as well. Coefficient of variation (Table 2), particularly for June are so high, it indicates how MOX could be attractive for speculators. The Coefficient of variation is high for Saurashtra, Kutch and Diu sub division. Though the variation reduces systematically in the subsequent months, but this is still higher than the variation of range bound stock indices, thus providing outstanding trading opportunities.

All this means that those who seek to hedge monsoon risk will have a new instrument to their hedging arsenal. Options on MOX would be still more attractive for the hedgers and speculators as well.

CONCLUSIONS

Rainfall index based insurance has emerged as a promising alternative to traditional crop insurance. Now attempts are directed towards exploring the scope and applicability of rainfall indexation to sub serve the capital market to meet the requirements of a wide-range of players whose financial prospects are closely inter connected to rainfall outcome. This study focused on rainfall–indexation and suggested a unique ticker symbol MOX for each of the sample meteorological subdivisions of India. An estimating function based on time-series simple regression is attempted to enable determination of expected MOX value at the end of the monsoon season. Essential statistical properties of MOX series are captured to indicate the vast scope for creating a new class of financial instrument for hedging and portfolio management purposes. Widespread availability of reliable data for long periods make it attractive to private insurers and international reinsurers and should help developing countries explore international markets for risk sharing.

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TABLES

TABLE 1: MOX VALUES FOR THE YEAR 1982-2011 FOR ALL MONSOON MONTHS

	For Assam-Meghalaya (ASMEG)				For Saurastra Katch and Diu (SAUKU)				For Madhya Maharastra (MADMH)			
YEAR	**JUN**	**JULY**	**AUG**	**SEPT**	**JUN**	**JULY**	**AUG**	**SEPT**	**JUN**	**JULY**	**AUG**	**SEPT**
1982	931	871	914	943	48	561	554	497	688	603	633	697
1983	698	978	990	1078	2562	1405	1477	1302	1000	881	1034	1217
1984	785	949	941	1014	448	449	601	840	705	986	819	838
1985	1039	1018	964	985	227	313	453	434	673	676	627	606
1986	604	704	754	810	1736	615	564	480	1631	912	901	819
1987	1044	1157	1112	1191	339	179	170	144	878	720	892	766
1988	844	1023	1288	1271	224	1722	1460	1606	710	1077	1069	1314
1989	933	1197	1099	1147	1981	1450	1318	1229	1142	1163	1051	1111
1990	867	822	795	863	345	246	894	926	1246	1020	1221	1092
1991	918	793	854	924	478	972	752	664	2158	1604	1319	1112
1992	729	771	820	819	553	1190	1068	1123	1097	870	968	943
1993	1474	1443	1446	1362	374	653	439	530	1072	1068	993	958
1994	930	812	845	841	1157	1644	1367	1546	1973	1449	1249	1109
1995	1037	979	1001	1036	101	940	699	879	555	785	889	833
1996	530	717	778	778	1999	1467	1040	904	1247	1133	1009	1008
1997	1080	927	886	934	2035	1271	1037	1277	1260	1066	1115	975
1998	1061	1096	1170	1061	1328	1323	1272	1185	1021	991	1068	1148
1999	749	934	1015	994	918	577	427	415	1284	1086	844	880
2000	941	797	939	1033	162	944	844	723	1308	1024	981	923
2001	725	749	734	744	2151	1502	1273	1101	954	715	721	881
2002	962	990	951	904	2165	913	955	837	1598	896	994	889
2003	961	856	874	853	641	1668	1616	1439	1110	938	874	814
2004	739	996	916	902	836	702	1012	929	1199	945	1140	1152
2005	969	867	986	897	1837	1179	931	1329	1582	1655	1584	1620
2006	1078	848	769	752	710	1719	1643	1553	1140	1463	1703	1572
2007	1141	1054	991	1033	1188	1201	1956	2083	1581	1396	1309	1251
2008	1073	941	1034	986	942	1042	918	1214	705	660	773	1019
2009	639	669	802	755	674	1814	1479	1273	402	956	884	941
2010	998	813	820	851	756	1756	1910	1970	1128	1194	1179	1153
2011	786	758	780	763	241	853	1236	1429	736	955	1012	1000

Source: IITM rainfall data to calculate MOX values

TABLE 2: STATISTICS FOR MOX VALUES FOR THE YEAR 1982-2011 FOR ALL MONSOON MONTHS

	For Assam-Meghalaya (ASMEG)				For Saurastra Katch and Diu (SAUKU)				For Madhya Maharastra (MADMH)			
Monsoon	**JUN**	**JULY**	**AUG**	**SEPT**	**JUN**	**JULY**	**AUG**	**SEPT**	**JUN**	**JULY**	**AUG**	**SEPT**
Mean	909	918	942	951	972	1076	1045	1062	1126	1029	1028	1021
Standard Deviation	192	166	162	155	747	487	454	465	408	268	244	227
Variance	36674	27644	26276	24001	557949	236943	205882	216201	166799	72082	59370	51743
Coeff of Variance	21.07	18.12	17.20	16.29	76.86	45.25	43.40	43.78	36.27	26.08	23.69	22.27

Source: IITM rainfall data to calculate MOX values

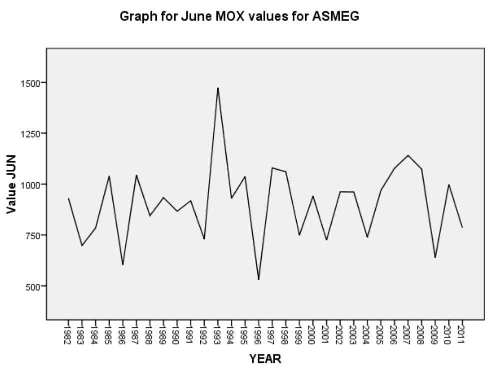
TABLE 3: CORRELATION ANALYSIS FOR MOX VALUES FOR SELECT SUB DIVISIONS FOR ALL THE 4 MONSOON MONTHS

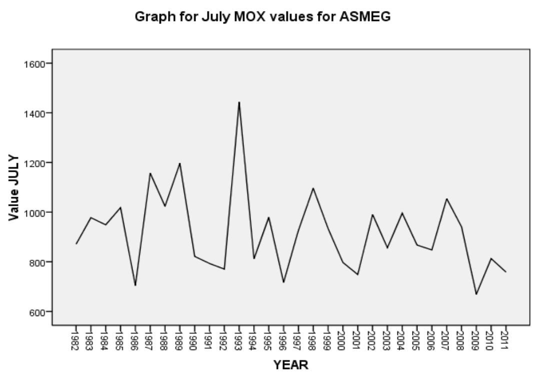
			For Assam-Meghalaya (ASMEG)				For Saurastra Katch and Diu (SAUKU)				For Madhya Maharastra (MADMH)			
Sub	Months	Particulars	JUN	JULY	AUG	SEPT	JUN	JULY	AUG	SEPT	JUN	JULY	AUG	SEPT
ASMEG	JUN	Pearson	1.00	.693**	.592**	.542**	-	-0.12	-0.06	0.06	0.03	0.13	0.20	0.10
		Sig. (2-tailed)		0.00	0.00	0.00	0.16	0.54	0.74	0.75	0.87	0.48	0.30	0.60
	JULY	Pearson	.693**	1.00	.888**	.871**	-	-0.27	-0.23	-0.17	-0.13	-0.08	-0.05	0.00
		Sig. (2-tailed)	0.00		0.00	0.00	0.78	0.15	0.22	0.36	0.48	0.66	0.80	1.00
	AUG	Pearson	.592**	.888**	1.00	.943**	-	-0.16	-0.24	-0.16	-0.19	-0.06	-0.09	0.06
		Sig. (2-tailed)	0.00	0.00		0.00	0.43	0.41	0.20	0.41	0.31	0.76	0.63	0.76
	SEP	Pearson	.542**	.871**	.943**	1.00	-	-0.26	-0.30	-0.23	-0.17	-0.10	-0.14	-0.03
		Sig. (2-tailed)	0.00	0.00	0.00		0.33	0.17	0.11	0.23	0.38	0.61	0.46	0.86
SAUKU	JUN	Pearson	-0.26	-0.05	-0.15	-0.18	1.00	0.36	0.27	0.21	0.36	0.16	0.17	0.26
		Sig. (2-tailed)	0.16	0.78	0.43	0.33		0.05	0.15	0.27	0.05	0.41	0.38	0.16
	JULY	Pearson	-0.12	-0.27	-0.16	-0.26	0.36	1.00	.836**	.768**	0.06	.374*	0.35	.499**
		Sig. (2-tailed)	0.54	0.15	0.41	0.17	0.05		0.00	0.00	0.76	0.04	0.06	0.01
	AUG	Pearson	-0.06	-0.23	-0.24	-0.30	0.27	.836**	1.00	.940**	0.07	.367*	.443*	.558**
		Sig. (2-tailed)	0.74	0.22	0.20	0.11	0.15	0.00		0.00	0.71	0.05	0.01	0.00
	SEP	Pearson	0.06	-0.17	-0.16	-0.23	0.21	.768**	.940**	1.00	0.07	.437*	.507**	.632**
		Sig. (2-tailed)	0.75	0.36	0.41	0.23	0.27	0.00	0.00		0.73	0.02	0.00	0.00
MADMH	JUN	Pearson	0.03	-0.13	-0.19	-0.17	0.36	0.06	0.07	0.07	1.00	.687**	.559**	0.33
		Sig. (2-tailed)	0.87	0.48	0.31	0.38	0.05	0.76	0.71	0.73		0.00	0.00	0.08
	JULY	Pearson	0.13	-0.08	-0.06	-0.10	0.16	.374*	.367*	.437*	.687**	1.00	.870**	.745**
		Sig. (2-tailed)	0.48	0.66	0.76	0.61	0.41	0.04	0.05	0.02	0.00		0.00	0.00
	AUG	Pearson	0.20	-0.05	-0.09	-0.14	0.17	0.35	.443*	.507**	.559**	.870**	1.00	.889**
		Sig. (2-tailed)	0.30	0.80	0.63	0.46	0.38	0.06	0.01	0.00	0.00	0.00		0.00
	SEP	Pearson	0.10	0.00	0.06	-0.03	0.26	.499**	.558**	.632**	0.33	.745**	.889**	1.00
		Sig. (2-tailed)	0.60	1.00	0.76	0.86	0.16	0.01	0.00	0.00	0.08	0.00	0.00	

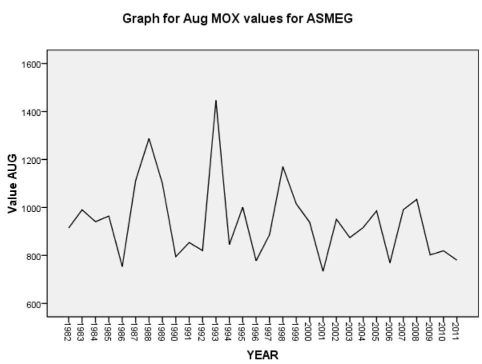
**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

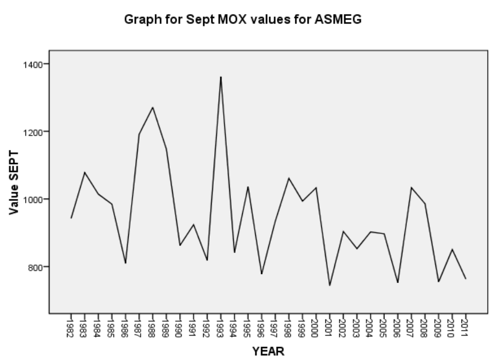
Source: IITM rainfall data to calculate MOX statistical values

GRAPH 1; (A),(B),(C),(D): ASSAM MEGHHALAYA SUB DIVISION MOX VALUES FOR JUNE,JULY,AUG,SEPT MONTHS OF MONSOON SEASON

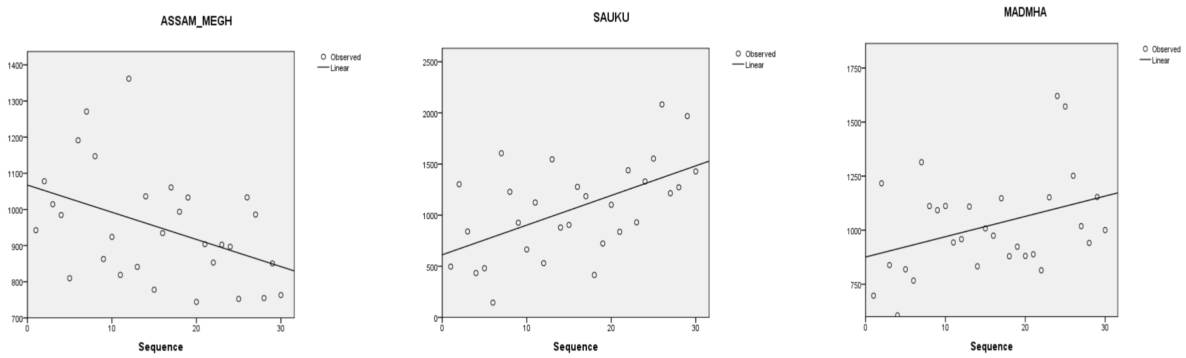








GRAPH 2(A),(B),(C): TREND FOR SEPT MOX VALUES FOR YEARS 1982-2011(30 YEARS) FOR SELECT SUBDIVISIONS



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