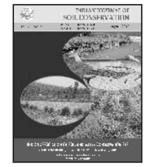
Vol. 46, No. 2, pp 199-205, 2018

Indian Journal of Soil Conservation

Online URL : http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home



Quantification of runoff, soil loss and yield of crops under different cropping systems in North Eastern ghat agro-climatic zone of Odisha

C.R. Subudhi, S.C. Senapati, Rageswari Subudhi and B. Panigrahi[1]

College of Agricultural Engineering and Technolgoy, Orissa University of Agricultural and Technology, Odisha.

[1]E-mail: kajal_bp@yahoo.co.in

ARTICLE INFO

Article history:

Received : December, 2016

Revised : June, 2018

Accepted : July, 2018

Key words:

Crop,

Equivalent yield,

Ground nut,

Pigeon pea,

Productivity,

Rainfall,

Runoff,

Soil loss

ABSTRACT

Experiments were conducted in the research farm of All India Coordinated Research Project on Dryland Agriculture (AICRPDA) of Orissa University of Agriculture and Technology at Phulbani in Kandhamal district during *kharif* season for three years from 2007 to 2009 with the objectives to quantify the runoff and soil loss under different cropping systems and develop relationship among them including development of relationship between rainfall *vs.* runoff and rainfall *vs.* soil loss. The treatments tried were T_1 - Sole crop of rice, T_2 - Sole crop of pigeon pea. T_3 - Sole crop of groundnut, T_4 - Pigeonpea and rice in alternate strips, T_5 - Pigeon pea and groundnut in alternate strips, T_6 - Intercrop of rice and pigeon pea (5:2),T_7 - Intercrop of groundnut and pigeon pea (4:2),T_8 - Uncultivated fallow, and T_9 - Cultivated fallow. All crops in treatments T_1 to T_7 were planted along the contour. Intercrop of groundnut and pigeon pea (4:2) (treatment T_7) gave significantly highest rice equivalent yield compared to other treatments in all the three years. Mean rice equivalent yield in treatment T_7 was found to be the highest with value of 55.57 q ha^{-1}. Pigeon pea and groundnut intercropping (2:4) increased the mean rice equivalent yield by 158.1, 96.8 and 21.4%, respectively when compared with sole crop of rice, pigeon pea and groundnut, respectively. Treatment T_7 gave the lowest runoff of 309 mm which is 23% less than the cultivated fallow *i.e.* treatment T_9 (400 mm). The same treatment also gave the lowest soil loss (8.03 t ha^{-1}) which is 47% lower than the treatment T_9 which gave the highest soil loss of 15.19 t ha^{-1}. Treatment T_7 was observed to give the lowest mean runoff (24.2% of rainfall) compared to other treatments. Relationship among rainfall, runoff and soil loss were developed and found to be satisfactory with high values of coefficient of determination (R^2 = 0.90). Hence the developed relationships (models) can be used to predict runoff and soil loss from known value of rainfall.

1. INTRODUCTION

Land and water are the two most important natural resources for crop production. Erratic and uneven rainfall distribution and subsequent soil and nutrient loss through runoff are the major problems prevalent in rainfed agriculture. Lack of proper water harvesting system in rainfed areas cause severe runoff and soil loss which cause degradation in most of the watersheds. A lot of runoff caused due to high intense storms goes as waste which should be recharged either in soil or underground water reservoir or else they can be harvested in low cost on farm storage structures like farm pond to utilse them for supplemental irrigation to crops (Panigrahi, 2009, Naik *et al.,* 2015). Sustainable production depends on health, vitality, and purity of production environment of which land and water are vital constituents. The need for proper planning, development, and management along with optimal utilization of the natural resources is of great importance for economic upgradation of resource poor farmers.

Arora and Gupta (2002) reported that there is a growing need for soil and rain water management since 96 M ha out of 142 M ha of net cultivated land of the country is rainfed. Scientific use of these resources along with conservation will definitely increase the productivity of rainfed lands. Improvement in soil conditions and soil-water regime to optimize crop production can be accomplished by runoff management techniques which vary with the situation depending on the existing conservation problems. Strip and intercropping of cereal crops with pulses/oilseeds are approved practices of breaking long slopes, which prevent soil loss, reduce runoff and enhance productivity. Samra (2002) reported that renovation of terrace and plantation of fruit plants, timber plants etc. improved biomass production, net returns, growth of crop and productivity of crops. There is reduction of runoff in range of 1.5-10.8 times, peak flow rate by 20 times and soil loss in the range of 1.2 to 5.2 times. Subudhi *et al.* (1999) reported that effect of vegetative barrier of Vetiver increased the rice yield and decreased the soil loss and runoff considerably compared to farmers practice.

Kumar (2002) reported that impact of different soil and water conservation (SWC) techniques *viz.*, contour bunding, terracing, land leveling, smoothening and gully plugging, sowing across the slope and vegetative barrier, increase the *kharif* crops by 25-30 percent. Establishment of vegetative barrier with mechanical measures were more effective in controlling soil erosion (3.8 t ha^{-1}) over conventional method (9.64 t ha^{-1}) and also in controlling runoff thereby making more moisture available for crop growth. Intercropping of pulses with oil seed crops on contour in sloppy watersheds have been reported by some authors to be promising measures to control soil and water erosion. Intercropping of groundnut with pigeon pea planted along contour gave the highest rice equivalent yield, lowest soil loss and runoff in north eastern ghat agro-climatic zone of Odisha (Anonymous, 2005). Rao *et al.* (2015) studied the efficacy of *Dichantium annulatum* grass in water courses at 2% land slope with varying grass coverage and flow rates and reported that this grass could be used as a effective filter materials to prevent runoff and soil loss from crop fields. Dass *et al.* (2011) carried on experiment in Kokriguda watershed of southern Odisha with various vegetative barriers in combination with trench-cum-bund and observed that sambusta (a local grass) planted on trench-cum-bund produced the lowest runoff (9.8%) and soil loss (5.5 Mg ha^{-1}) than other vegetative barriers. Sudhishri *et al.* (2008) reported that at 11% slope, sambusta grass reduced the runoff and soil loss by 63.4% and 68.6%, respectively over the control having runoff 25.9% and soil loss 14.0 t ha^{-1}. Moreover this vegetative barrier resulted in increased yield of finger millet plated inside the plot between the vegetative barriers. Impact of different SWC measures including agronomical and engineering measures on runoff, soil, loss and productivity of crops have also been done by several other researchers (Behera *et al.,* 2014; Naik *et al.,* 2014; Panigrahi, 2008; Panigrahi, 2007; Singh and Khera, 2006).

A review of earlier research works done elsewhere in the country and outside reveals that a number of SWC measures including both agronomical and engineering measures are now being practiced in various regions to reduce soil and water erosion. However, these conservation practices cannot be applied in toto in other regions since they are site specific depending on local soil and management conditions. Kandhamal district of Odisha is bestowed with high rainfall (annual average rainfall is 1645 mm). Much of this rainfall flows past over the sloppy land causing serious soil erosion. Very few research works have been done in this area on SWC measures. Therefore, this experiment has been designed with objectives to quantify the effect of strip as well as intercrop of pigeon pea, rice and groundnut on runoff, soil loss and productivity of crops on sloppy agricultural land in this typical rainfed area (Kandhamal district) in North Eastern ghat agro-climatic zone of Odisha.

2. MATERIALS AND METHODS

The present experiment was undertaken at the experimental field of AICRPDA at Phulbani, Odisha. Phulbani is a tribal dominated belt lying in the district of Kandhamal, Odisha. Latitude and longitude of the study area is $20^0$27'01''N and $84^0$14'16''E, respectively with altitude of 553 m above mean seas level (msl). The district comes under North Eastern ghat agro-climatic zone of Odisha with tropical moist sub humid climate. The average annual rainfall of the area is 1550 mm out of which 77% occur in rainy/*kharif* season (June to September). The maximum temperature of the area goes upto 44°C in May and the minimum goes up to 4°C in December. Irrigation facility (canal) is very poor since the land is highly undulating. In addition, there is large patch of small and fragmented land holdings and undulated topography. The soil of the study area is sandy loam with poor water holding capacity. People are mostly backward with large crunch of population lives below properly line. Hardly any crop is grown in *rabi*. Paddy is the main crop grown in almost all types of toposystems in *kharif*. In addition to paddy, some people grow maize, arhar, black gram, pigeon pea, ground nut and vegetables like tomato, cabbage etc. in small patches of lands.

Research studies were conducted in the experiment fields during *kharif* season for three consecutive years. The experiment was laid out on 2% land slope. There were total 9 treatments with three replication each. Thus, there were total 27 plots. The nine treatments tried were (i) T_1 - Sole crop of rice, (ii) T_2 - Sole crop of pigeon pea. (iii) T_3 - Sole crop of groundnut, (iv) T_4 - Pigeonpea and rice in alternate strips, (v) T_5 - Pigeon pea and groundnut in alternate strips, (vi) T_6 -Intercrop of rice and pigeon pea (5:2), (vii) T_7 - Intercrop of groundnut and pigeon pea (4:2), (viii) T_8 - Uncultivated fallow, and (ix) T_9 - Cultivated fallow. All crops in treatments T_1 to T_7 were planted along the contour. Different crops and their varieties grown in the plots in all three years are: Rice - ZHU-11-26, Pigeon pea - UPAS - 120 and Groundnut- Smruti (OG-52-1). The experiment design was randomized block. Gross plot size in each treatment were 25 x 2 m with net plot size of 21.8 x 1.5 m. Seed rate used in crop growing case were, rice - 75 kg ha^{-1}; pigeon pea - 25 kg ha^{-1} and groundnut - 150 kg ha^{-1} (pod). Crops were grown as per the recommended cultivation practices. Intercultural and other crop management practices were followed as per standard practice. Pesticides and insecticides were applied as and when required as per the standard practices. Crops were grown/sown in the fields at the onset of monsoon each year *i.e.* 12th June in 2007, 16th June in 2008 and 15th June in 2009. Crops and their varieties were so selected that they were harvested before the withdrawal of monsoon from the region. This planning helps in maximum utilization of monsoon rainfall so that yield of the crops are not hampered in rainfed ecosystem.

Multi slot division box and drums were put at the downstream end of each plot to measure the runoff and soil loss daily after each rainfall. The runoff collected daily at 8 am was measured from the drum and 1 lit of runoff from each drum was collected for silt analysis. Soil loss was measured from the silt sample collected after drying the sample. The rainfall was also measured daily for each treatment by a non-recording raingauge which was put very near the experimental site. From the daily values of rainfall, runoff and soil loss, weekly, monthly and seasonal values were worked out. Rainfall, runoff and soil loss data of each treatment were collected from the onset day of monsoon to withdrawal day of monsoon of each year. Onset and withdrawal date of monsoon were 12th June and 28th September, respectively in 2007, 16th June and 2nd of October, respectively in 2008 and 15th June and 30th September, respectively in 2009. Yield of crops were recorded for each treatment. Since there were different crops grown in the experimental plots in a given season, for comparison of yield data, the rice equivalent yield data were computed. Rice equivalent yield of different crops like ground nut and pigeon pea and the intercropping systems were finally calculated taking the yield and selling price of the produces.

Yield data of rice and rice equivalent yield data of other crops along with data of the statistical analysis were worked out. Economics of different treatments were computed considering the cost of cultivation and gross returns from the harvested yield of crops in each year. The economic parameters like net income and benefit-cost (B:C) ratio were then computed using these data. Seasonal values of rainfall, runoff and soil loss data of each treatment for all the three years alongwith the statistical parameters are also worked out. Values of percentage of runoff of the total seasonal rainfall of each treatment in each year were calculated from the seasonal values of rainfall and runoff. Variation of mean data (mean of three years) of runoff, soil loss and rice-equivalent yield of crops in various treatments in different years were also studied. Relationships among the mean seasonal values of rainfall, runoff, and soil loss for various treatments for various years were also developed.

3. RESULTS AND DISCUSSION

Yield of Crops

Experimental results reveal that mean yield of sole crop of rice obtained from the study was 21.53 q ha^{-1}, whereas that of sole crop of groundnut and pigeon pea is 45.79 and 28.23 q ha^{-1}, respectively. However, with the introduction of intercropping, the yield of all crops increased (Table 1). Intercropping of pigeon pea and groundnut (2:4) was found to give significantly the highest rice equivalent yield in all the years. Values of REY of treatment T_7 with inter-cropping of pigeon pea and ground nut (2:4) gave the highest yield of 65.996, 49.043 and 51.68 q ha^{-1} in 2007, 2008 and 2009 with mean value of 55.57 q ha^{-1}. The mean yield of treatment T_7 was observed to be 158% higher than the mean yield of sole rice and 97% and 21% more than the sole yield of pigeon pea and ground nut, respectively. The pigeon pea and ground nut intercropping planted along the contour has reduced the runoff and soil loss and has increased the moisture content of the soil which has a significant effect on growth of the crops, enhancing water use efficiency of the crops and this may be the reason why it gives the highest yield.

Table: 1
Yield of rice and rice equivalent yield of other crops and cropping systems under different treatments in different years

Treatments	Yield of rice and REY (q ha^{-1})			
	2007	2008	2009	Mean
T_1 - Rice (sole)	21.047	21.17	22.38	21.53
T_2 - Pigeon pea (sole)	33.393	25.436	25.85	28.23
T_3 - Ground nut (sole)	54.179	41.307	41.87	45.79
T_4 - Pigeon pea and rice strip cropping	37.528	32.584	33.70	34.6
T_5 - Pigeon pea and ground nut strip cropping	53.784	42.448	44.25	46.83
T_6 - Rice and Pigeon pea inter cropping (5:2)	40.429	35.843	37.08	37.78
T_7 - Pigeon pea and ground nut (2:4) intercropping	65.996	49.043	51.68	55.57
T_8 - Uncultivated fallow	--	--	--	–
T_9 - Cultivated fallow	--	--	--	–
SE (m)+	0.961	0.612	0.601	0.586
CD (0.05)	2.914	1.885	1.823	1.778
Mean	43.78	35.404	36.69	38.62

Economics of Cropping System

Economics of sole crop and cropping systems for various treatments were computed from the data of cost of cultivation and gross income which is obtained from the yield data and selling price of the crops. The mean values of these data are presented in Table 2 for all treatments. Net income is computed by subtracting cost of cultivation from gross income. B:C ratio was computed by dividing gross income with cost of cultivation. Mean values of net income and B:C ratio for various treatments are presented in Table 2. It is found that net income and B:C are the highest for treatment T_7 with values of ₹ 23,834 ha^{-1} and 2.06, respectively (Table 2). Though the cost of cultivation of crops in treatment T_7 with intercropping of pigeon pea and groundnut (2:4) was highest (₹ 22,577 ha^{-1}), the gross return from the yields was also highest (₹ 46,411 ha^{-1}) for this treatment which helped to increase the net income and B:C value. Growing of sole crop of rice, pigeon pea and ground nut gave net incomes of ₹ 3933 ha^{-1}, ₹ 9191 ha^{-1} and ₹ 17861 ha^{-1}, respectively. Thus, the study reveals that intercropping of crops give more yield and remuneration than sowing only a single crop in the rainfed areas.

Rainfall, Runoff and Soil Loss

Seasonal values of rainfall, runoff and soil loss for various treatments and for various years presented in Table 3. Runoff was observed to vary with rainfall for each treatment. The year which received higher amount of seasonal rainfall, it produced higher amount of runoff and soil loss. Runoff as percentage of rainfall for various treatments in various years are shown in Fig. 1. As seen from Fig. 1, runoff varied from 20.88 to 24.51% of seasonal rainfall in 2007 for various treatments. In 2008, there was more rainfall than 2007 and so runoff in 2008 varied from 22.09 to 31.25% of

Table: 2
Economics of different treatments as affected by different in-situ conservation practices

Treatments	Cost of cultivation (₹ ha^{-1})	Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	Benefit:Cost Ratio
T_1 - Rice (sole)	14,000	17,933	3,933	1.28
T_2 - Pigeon pea (sole)	14,200	23,391	9,191	1.65
T_3 - Ground nut (sole)	21,721	39,582	17,861	1.82
T_4 - Pigeon pea and rice strip cropping	17,861	28,866	11,005	1.62
T_5 - Pigeon pea and ground nut strip cropping	19,294	38,839	19,545	2.01
T_6 - Rice and Pigeon pea inter cropping (5:2)	19,166	32,222	13,056	1.68
T_7 - Pigeon pea and ground nut (2:4) intercropping	22,577	46,411	23,834	2.06

Table: 3
Seasonal values of rainfall, runoff and soil loss for different treatments in different years

Treatments	Rainfall, (mm)				Runoff (mm)				Soil loss (t ha^{-1})			
	2007	2008	2009	Mean	2007	2008	2009	Mean	2007	2008	2009	Mean
T1	1011	1060	1380	1151	221	295	514	343	6.72	10.01	12.60	9.77
T2	1020	1168	1545	1244	227	296	516	346	7.11	10.06	12.65	9.94
T3	941	1064	1439	1148	222	284	508	338	6.49	9.35	12.43	9.42
T4	1020	1168	1545	1244	221	279	487	329	6.47	9.59	11.84	9.30
T5	1020	1168	1545	1244	220	276	482	326	6.70	9.47	11.75	9.31
T6	1020	1168	1545	1244	218	270	471	319	6.35	9.32	9.81	8.49
T7	1020	1168	1545	1244	213	258.4	456	309	6.23	8.61	9.25	8.03
T8	1020	1168	1545	1244	234	347.7	555	379	7.40	11.92	17.84	12.38
T9	1020	1168	1545	1244	250	364.7	588	40	9.77	16.0	19.8	15.19
SE (m) +					8.99	29.28	34.1	23.90	0.89	1.84	2.85	1.82
CD (0.05)					19.06	62.09	72.3	50.68	1.89	3.91	6.04	3.86

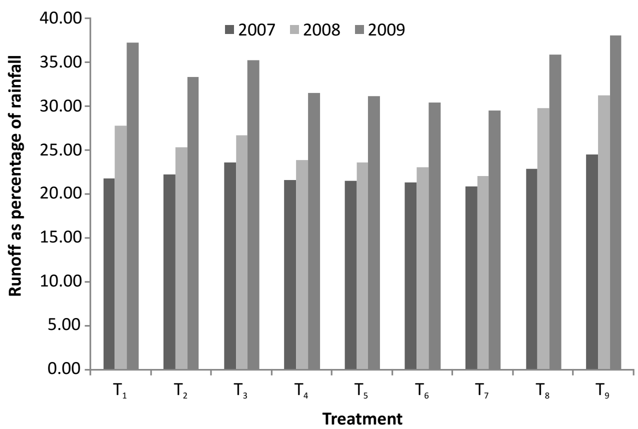


Fig. 1. Runoff as percentage of rainfall for various treatments in various years

seasonal rainfall for different treatments. Similarly, the year 2009 received the highest seasonal rainfall as compared to 2007 and 2008 and hence in this year the runoff varied from 29.51 to 38.66% of seasonal rainfall (Fig. 1).

Moreover, it was seen that runoff and soil loss were dependent on type of treatments *i.e.* crops and cropping system. Mean values of runoff in treatment T_8 (uncultivated fallow) and T_9 (cultivated fallow) were 379 and 400 mm, respectively. Treatment T_7 with inter-cropping of pigeon pea and ground nut (2:4) gave significantly the lowest values of runoff in all the years with values of 213, 258.4 and 456 mm in 2007, 2008 and 2009, respectively with mean value of 309 mm (Table 3). The mean value of runoff in this treatment (T_7) was 18.5% and 22.8% less than that of treatment T_8 and T_9, respectively. The reason of getting lowest value of runoff in treatment T_7 may be due to more crop coverage areas (canopy areas) by pigeon peas and ground nuts which intercepted maximum amount of rainfall, increased more water to go into the soil as infiltration and thereby reducing runoff. This production of less runoff also facilitated in giving significantly the lowest amount of soil loss by treatment T_7 in all the years (6.23 t ha^{-1} in 2007, 8.61 t ha^{-1} in 2008 and 9.25 t ha^{-1} in 2009) with mean value of 8.03 t ha^{-1} (Table 3). The soil loss was found to be the highest in treatment T_9 (cultivated fallow) with mean value of 15 19 t ha^{-1} which is 89% higher than treatment T_7. The next highest value of soil loss was produced by treatment T_8 (uncultivated fallow) with mean value of 12.38 t ha^{-1} which is 54% higher than treatment T_7.

Mean values of runoff as percentage of rainfall, rice equivalent yield and soil loss in different treatments are presented in Fig. 2. Data of this figure reveals that treatment T_7 with intercropping of pigeon pea and groundnut (2:4) on contour significantly reduces runoff and soil loss and at the same time gives significantly the highest rice equivalent yield 55.57 q ha^{-1} and so it is recommended that this

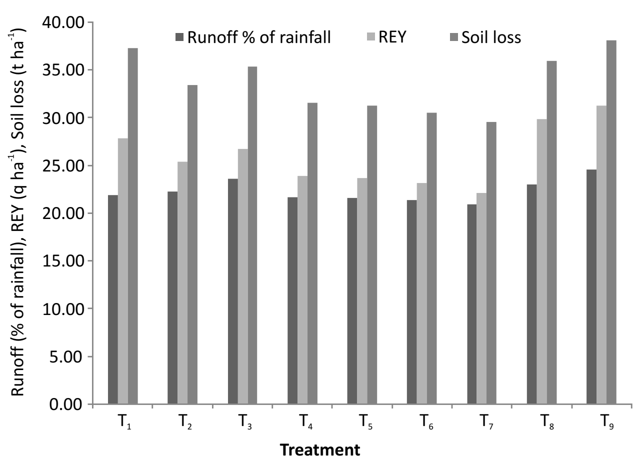


Fig. 2. Mean values of runoff, rice equivalent yield and soil loss in different treatments

treatment is the best from SWC point of view in north eastern ghat agro-climatic zone of Odisha.

Development of Relation among Rainfall, Runoff and Soil Loss

Seasonal values of rainfall, runoff and soil loss for various treatments were used to develop relationships among these hydrologic variables and the developed relations in the form of linear and quadratic equations with values of coefficient of determination (R^2) are presented in Table 4. It is observed that linear and in some case second degree quadratic equations were present among the variables. Higher value of R^2 (more than 0.90 in all equations) reveals that the developed equations can be used to predict runoff and soil loss if occurrence of rainfall is known. In other words, by the observed rainfall data, one can use the equations to predict runoff and soil loss for a given treatment. Thus, the developed equations can be of great help to the planners and design hydrologic and hydraulic engineers to predict the runoff and soil loss and accordingly watershed planning and developmental works can be designed for the region.

4. CONCLUSIONS

Three years of field experiments conducted at dry land research farm under OUAT reveals that pigeon pea and groundnut intercropping (2:4) (Treatment T_7) increased significantly the mean rice equivalent yield by 158.1, 96.8 and 21.4%, respectively when compared with sole crop of rice, pigeon pea and groundnut, respectively. This treatment T_7 gave significantly the lowest runoff of 309 mm which was 23% less than the cultivated fallow *i.e.* treatment T_9 (400 mm). The same treatment also gave the lowest soil loss (8.03 t ha^{-1}) which is 47% lower than the treatment T_9 which gave the highest soil loss of 15.19 t ha^{-1}. Treatment T_7 was observed to give the lowest mean runoff of percentage of rainfall (24.2%) compared to other treatments. Thus it can be concluded that intercropping of pigeon pea groundnut (2:4) planted along contour may be practiced to increase crop yield and lowering the soil loss and runoff in the hilly tribal areas of Kandhamal district in north eastern ghat agro-climatic zone of Odisha.

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Table: 4
Relation between rainfall (X), Runoff (Y) and Soil loss (Z) in different treatments along with values of co-efficient of determination

Treatment	Rainfall (X) and Runoff (Y)	Rainfall (X) and Soil loss (Z)	Runoff (Y) and Soil loss (Z)
T_1	$Y = -0.49+0.176X+0.002X^2$ (0.975)	$Z = -0.008+0.001X+0.0001X^2$ (0.972)	$Z = -0.086+0.038Y$ (0.983)
T_2	$Y = -0.43+0.175X+0.002X^2$ (0.975)	$Z = -0.007+0.001X+0.0001X^2$ (0.973)	$Z = -0.088+0.039Y$ (0.983)
T_3	$Y = -0.46+0.176X+0.002X^2$ (0.975)	$Z = -0.01+0.002X+0.0001X^2$ (0.972)	$Z = -0.081+0.037Y$ (0.986)
T_4	$Y = -0.525+0.179X+0.002X^2$ (0.973)	$Z = -0.009+0.002X+0.0001X^2$ (0.972)	$Z = -0.082+0.037Y$ (0.987)
T_5	$Y = -0.567+0.18X+0.002X^2$ (0.974)	$Z = -0.009+0.001X+0.0001X^2$ (0.971)	$Z = -0.083+0.038Y$ 0.982)
T_6	$Y= -0.586+0.181X+0.002X^2$ (0.972)	$Z = 0.016+0.002X+0.0001X^2$ (0.949)	$Z = -0.064+0.035Y$ (0.967)
T_7	$Y= -0.586+0.172X+0.002X^2$ (0.97)	$Z = 0.014+0.002X+0.0001X^2$ (0.943)	$Z = -0.068+0.035Y$ (0.966)
T_8	$Y= -0.227+0.161X+0.003X^2$ (0.974)	$Z = -0.007+0.001X+0.0002X^2$ (0.97)	$Z = -0.105+0.042Y$ (0.985)
T_9	$Y= -0.153+0.15X+00003X^2$ (0.965)	$Z = -0.007+0.001X+0.0002X^2$ (0.872)	$Z = -0.104+0.048Y$ (0.993)

N.B. Data in parenthesis give values of coefficient of determination

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