Flood Threat on Cereal Crops Production in Irrigated and Rainfed Agriculture: A Study of Selected Indian States

Md Aktar Hussain, Pradyut Guha

ABSTRACT

Background: As one of the various forms of exogenous threat for agriculture, flood, a recurrent phenomenon in several Indian states has severe impact on agriculture and damages substantial amount of crops annually. There is a dearth of scholarly attempt to understand flood threat on each cereal crop output in irrigated and rainfed setup. The present study aimed to examine the threat of flood on cereal crops output in irrigated and rainfed agriculture during 1990-91 to 2016-17 using data of 17 selected Indian states from various published sources.

Methods: Three stage least squares estimation technique was used for jointly determining association of flood affected area with output of cereals crop together with impact of annual average rainfall, irrigation infrastructure on spread of flood.

Result: The result reveals that output of cereal crops have positive significant association with area under farming while the relationship found to be inverse with area affected by flood. Surprisingly the irrigation infrastructure has been seen to be contributory towards spread of flood in the study area.

Key words: Cereal crops, Flood threat, Irrigated and Rainfed agriculture.

INTRODUCTION

One of the various forms of exogenous threat for Indian agriculture is flood which damages substantial amount of crop annually. Being a recurrent phenomenon in some states of India, flood has severe impact on agriculture for its vulnerability and exposure to the calamity. As per the report of National Disaster Management Authority (2012) during 1953-2016 the annual average area of the India is affected by flood was 15.3 per cent, damaging worth of INR 5,431 crore (Central Water Commission of India, 2018). Generally, minimum water and sunshine are critical for photosynthesis and plant growth, however excessive flow of water may be threatful for growth of plant and agriculture. Proper channelisation of excessive rain water during monsoon is important in the light of minimisation of flood threat in flood plains as most of the agrarian states of India are basin of rivers and their tributaries notably Uttar Pradesh, Bihar, West Bengal, Odisha, Assam. In a developing economy like India, raising agricultural output (cereal crops) is crucial for food security of the growing population and for the farmers who are directly or indirectly dependent on agriculture for their livelihood. Being the largest producer [1] and exporter [2] in the world, the cereal crop cultivation in India spread over 51.3 per cent of gross cropped area (GCA) during 2014-15 (Anonymous, 2019). Though farm mechanization and improvement in agricultural infrastructure post green revolution period has helped in attaining higher level of yield, but exogenous threat of flood and dependency on rainfall remained critical in some of the Indian states. The knowledge about, does flood affects production of cereal crop differently the irrigated and rainfed agriculture, may help the farmers in appropriate selection of crops in a particular season with specific agrarian setup. While understanding the contributory factors towards the problem of flood may help the policy makers in formulation of policy for creation of basic infrastructure to cope with the problem.

The threat of flood on agriculture has been the area of investigation in the works of Mandal and Bezbaruah (2013); Goyari (2005). Huang et al. (2015) and Banerjee, (2010) remarked severe flooding decreases agricultural production, specifically the rice output. Farmers’ strategies to deal with the flood threat in Indian states being investigated by Mandal (2010) and Emerick et al. (2016). Existing literature studies the impact of flood on agriculture across countries as well as in Indian states has mostly paid attention on the farm level strategies in coping with adverse impact of flood. Besides, the earlier studies focused on district level analysis and restricted them to geography of a state. Scholarly attempt to understand flood threat on a wide range cereal crops output in irrigated and rainfed setup across Indian states seems to be conspicuous by its absence. The novelty of present study is to look at the problem across a wide range of Indian states which has not been studied before,
besides investigating the role of agricultural infrastructure such as irrigation and rainfall on spread of flood.

**MATERIALS AND METHODS**

**Data source and study area**

The study is based on the secondary panel data compiled from various published sources covering the period from 1990-91 to 2016-17. The selection of the study period was constrained by non availability of reliable and consistent data. The cross section of the study includes 17 Indian states which area listed as irrigated and rainfed states of Indian agriculture. The evidence of flood occurrence in the state for more than one third of period under consideration (i.e. more than nine years) was the basis for selection of the states based on the data on the state wise cropped area affected by flood as collected from the Flood Damage Statistics, 2018 published by Central Water Commission, Government of India (GoI). Regional level annual rainfall data was obtained from the Indian Meteorological Department, which was rearranged for selected states of the study falling in particular region. The data on area and production of cereal crops, usage of fertilizer and net irrigated area were obtained from the Ministry of Agriculture and Farmers Welfare (MAFW), GoI.

From the results of summary statistics it is obvious that Bihar, Assam, West Bengal, Uttar Pradesh and Odisha can be listed as highly flood affected states of India during 1990-2016 (Table 1). Despite having largest area affected by flood in Uttar Pradesh, the state has been subject of water level crossing red alert in some years while dry spell in some years. The lower standard deviation with mean value of area affected by flood being high in Assam and Bihar signifies that flood threat has been consistently devastating in these two states during the reference period, while the dispersion in the occurrence of flood has been found to be higher in states like Karnataka, Odisha, Andhra Pradesh, Jammu and Kashmir, Madhya Pradesh, Punjab and Tamil Nadu. The states like Karnataka and Andhra Pradesh having unanticipated result of high flooding for the reference period possibly due to the existence of outliers in the data, which may be treated as data limitation of the study. Incapability of watercourses to drain away water during an unusually heavy rainfall being traced as the important factor resulting in flood (Asaduzzaman, 1994).

The Fig 1. shows that in the states like Kerala, Arunachal Pradesh, Assam and West Bengal recorded high level of average annual rainfall for the period of study. States like Arunachal Pradesh, Assam, Karnataka, Kerala, Manipur, Odisha, Tripura and West Bengal reported to have annual rainfall above the 1000 mm during the reference period. Rajasthan, Haryana and Punjab had received minimal level of annual rainfall during the same period.

With the aim of the study being joint determination of the association of flood affected area with output of cereal crops and relationship of annual average rainfall, irrigation infrastructure with spread of flood across the states being selected. The functional form of model formulated for investigating such joint association was;

\[
Q = f(Ar, Aa, Fr) \quad (i)
\]

\[
Aa = f(Rf, la) \quad (ii)
\]

Since single equation method of estimation don’t account for the restrictions on other equations of the system in a set of simultaneous equation, hence for the above set of simultaneous equations, three stage least squares (3SLS) estimation technique being applied for finding the association of flood affected area and output of cereal crops across the sampled states. Zellner and Theil (1962) introduced 3SLS as a system method which takes into account all equation of the system at the same time. Asymptotic efficiency of 3SLS over 2SLS was the reason for selection of the estimation technique with prior confirmation of status of identification (5). Works of Theil (1964); Turkington (1985); Rothenberg and Leenders (1964) outlined superiority of 3SLS over 2SLS and SURE methods. In the field of agriculture several scholars used 3SLS method.
Flood Threat on Cereal Crops Production in Irrigated and Rainfed Agriculture: A Study of Selected Indian States

(e.g. Swinnen et al. 2001; Niles et al. 2013) in their empirical illustration. The econometrics specification of the model fitted in equation (i) and (ii) in log linearised form being specified as follows;

\[ \ln Q_{ijt} = \lambda_1 + \lambda_2 \ln Ar_{ijt} + \lambda_3 \ln Aa_{ijt} + \lambda_4 \ln Fr_{ijt} + U_{ijt} \]  
\[ \ln Aa_{ijt} = \lambda_5 + \lambda_6 \ln Rf_{ijt} + \lambda_7 \ln Ia_{ijt} + V_{ijt} \]

Where,

i = 1, 2, 3, 4, 5, 6, 7, 8, 9 crops of the study under consideration viz. paddy, wheat, jowar, bajra, maize, ragi, barley, other cereals and millets, total cereals; j = 1, 2, ..., 17 being the number of states considered for the study; t = 1990, 1991, 1992, ..., 2016 being the 27 years period of study; \( \lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5, \lambda_6, \lambda_7 \) are the parameters to be estimated; Q is crop output (in '000 hectare); Ar is area under farming (in '000 hectare); Aa is area affected by flood (in '000 hectare), Ia is irrigated area (in '000 hectares), Fr is fertiliser consumed (kg/'000 hectare) and Rf is rainfall (in millimeter). Though the variables selected were used in several studies but there is absence of studies to find out the simultaneous impact of flood threat on crop output. Rainfall and irrigation are considered as exogenous enabling input factors and fertilizer can be termed as a plant nutrient. The non availability of consistent and reliable data on high yielding verities of seeds and pesticides for the study period covering the states under consideration was the reason for excluding them from the study. The study was carried as a part of research work in Sikkim University.

RESULTS AND DISCUSSION

There seems to be significant association between output

### Table 1: State Wise Cropped Area Affected by Flood (1990 – 2016).

| State                  | Mean | SD  | Min | Max | NYA |
|------------------------|------|-----|-----|-----|-----|
| Andhra Pradesh (AP)    | 395  | 567 | 0   | 1995| 18  |
| Arunachal Pradesh (AR) | 31   | 70  | 0   | 310 | 15  |
| Assam (AS)             | 316  | 374 | 0   | 1470| 23  |
| Bihar (BR)             | 446  | 383 | 0   | 1399| 25  |
| Chandigarh (CH)        | 0    | 0   | 0   | 0   | 0   |
| Chhattisgarh (CG)      | 13   | 25  | 0   | 89  | 8   |
| Dadra and Nagar Haveli (DN) | 0   | 0   | 0   | 0   | 0   |
| Daman and Diu (DD)     | 0    | 0   | 0   | 0   | 0   |
| Delhi (DL)             | 6    | 30  | 0   | 155 | 2   |
| Goa (GA)               | 0    | 1   | 0   | 4   | 2   |
| Gujarat (GJ)           | 123  | 275 | 0   | 1050| 8   |
| Haryana (HR)           | 54   | 125 | 0   | 543 | 13  |
| Himachal Pradesh (HP)  | 141  | 151 | 0   | 476 | 19  |
| Jammu and Kashmir (JK) | 39   | 137 | 0   | 651 | 4   |
| Jharkhand (JH)         | 5    | 12  | 0   | 41  | 2   |
| Karnataka (KA)         | 357  | 841 | 0   | 3780| 17  |
| Kerala (KL)            | 58   | 138 | 0   | 578 | 21  |
| Madhya Pradesh (MP)    | 249  | 748 | 0   | 3670| 15  |
| Maharashtra (MH)       | 33   | 89  | 0   | 391 | 14  |
| Manipur (MN)           | 36   | 18  | 0   | 54  | 23  |
| Meghalaya (ML)         | 4    | 7   | 0   | 29  | 8   |
| Mizoram (MZ)           | 9    | 37  | 0   | 189 | 4   |
| Nagaland (NL)          | 0    | 2   | 0   | 9   | 2   |
| Odisha (OD)            | 332  | 765 | 0   | 3970| 23  |
| Puducherry (PY)        | 5    | 8   | 0   | 22  | 8   |
| Punjab (PB)            | 256  | 518 | 0   | 1759| 20  |
| Rajasthan (RJ)         | 139  | 247 | 0   | 842 | 18  |
| Sikkim (SK)            | 0    | 2   | 0   | 6   | 3   |
| Tamil Nadu (TN)        | 52   | 121 | 0   | 383 | 9   |
| Tripura (TR)           | 6    | 11  | 0   | 53  | 15  |
| Uttar Pradesh (UP)     | 510  | 630 | 0   | 2955| 22  |
| Uttarakhand (UK)       | 5    | 15  | 0   | 59  | 4   |
| West Bengal (WB)       | 340  | 598 | 0   | 2490| 25  |

Source: Central Water Commission (2018), Government of India.

Notes: NYA stands for Number of Years flood occurred in between 1990-2016; Area is in '000 hectares.
of selected cereal crops and area affected by flood; as per the estimated Chi square test statistic (Table 2). As the application of 3SLS requires set of simultaneous equations to be over identified, so the over identification status of the fitted equation was confirmed via rank and order conditions (Table 3). Post estimation of 2SLS, the existence of endogeneity was detected as per the diagnostics test of the fitted set of equations using Wu-Hausman test (Table 4). The crop wise results of three stage least squares (3SLS) estimates being reported in Table 5. As per the estimated result of set of simultaneous equations; it can be noticed that most of the estimated coefficients are statistically significant with expected sign of the relationship with endogenous variables, barring irrigation (Table 5). From the estimates of simultaneous regression model it can be observed that across the sampled states of present study the area under farming being found to be statistically significant with positive elasticity in the first equation of the system, implying that the level of output moves along with the area under cultivation of cereal crops. However, the area affected by flood has found to be negative and statistically significant in most of the selected set of cereal crops, suggesting that output of these crops might have declined with increase in area affected by flood across the states of present study for the reference period. Possible explanation of such result implies that an expansion in area affected by flood causes greater damage towards cultivation of crop thereby lowering the output level. Similar findings being arrived in the works of Younus (2014); Huang et al. (2015); and Das and Bora (2020). The estimated coefficient of consumption of fertiliser in cultivation of crops like paddy, jowar, ragi, barley and total cereals seen to be statistically significant with positive elasticity. However, the significant negative coefficient estimate of fertiliser for crop like other cereals implies in case of such crops the fertiliser use was less helpful in attaining incremental level of output across the selected states of present study. Possible explanation may be application of fertiliser to a permissible limits helps in enhancement of output of a crop by acting as a plant nutrient, however over application of fertiliser may harm the growth and yield of a plant. In the study area possibly the fertiliser application was not as per permissible limit in case of the crops like wheat, maize and other cereals thereby reduced the output of these crops.

As per the estimated result reported in Table 5; the coefficient of rainfall being found to be positive and statistically significant in the second equation of the system, implying that rain water to some extent contributed towards flood in the states of present study during the reference period. Similar findings being arrived at in the studies by Asaduzzaman (1994); Meena et al. (2016), as they found that severity rainfall has significant positive role in flooding. Hence, across the selected states of the lower output of cereal crops was largely influenced by area affected by flood where rain-water made important contribution. Irrigation is an important form of agricultural infrastructure which has the characteristics of controlling flood through proper channelisation of river water to the agricultural fields. Exceptionally present set of estimate suggests that spread of irrigation contributed towards expansion of area affected by flood across the selected states during the reference period. Possible reason for such result may be drawn from the fact that the states of present study which are highly flood prone with agriculture being based on rainfed farming

### Table 2: Association of cropped area affected by flood and crop output (1990-2016).

| Crop       | Output          | Crop Area  |
|------------|-----------------|------------|
| Paddy      | 3675.21(0.00)   | 17.10(0.00) |
| Wheat      | 14534.86(0.00)  | 13.04(0.00) |
| Jowar      | 3721.60(0.00)   | 17.09(0.00) |
| Bajra      | 2921.67(0.00)   | 17.92(0.00) |
| Maize      | 546.04(0.00)    | 19.05(0.00) |
| Ragi       | 2643.43(0.00)   | 27.92(0.00) |
| Barley     | 1757.06(0.00)   | 25.23(0.00) |
| Others Cereals | 1373.21(0.00) | 20.26(0.00) |
| Total Cereals | 2181.64(0.00) | 15.50(0.00) |

Sources: Authors Estimation from data collected from 1. Ministry of Agriculture and Farmers’ Welfare, GoI; 2. India Meteorological Department, GoI; 3. Central Water Commission, GoI.

Notes: Figures outside the bracket are Chi Square values and probability (p) values in the bracket; Chi Square values are simultaneously obtained from 3SLS estimates as reported in Table 2

### Table 3: Test of identification.

| Conditions | Equation (i) | Equation (ii) |
|------------|--------------|---------------|
| Order (A-B) ≥ (G-1) | 2 > 0 | 3 > 0 |
| Rank | ρ(Δ) = (T-1) | 1 | 1 |

Notes: A is no. of predetermined variables in the model; B stands for no. of predetermined variables in a particular equation; G stands for number of endogenous variables in a particular equation; ρ stands for the matrix of excluded variables at the rest of the equation of the system of simultaneous equations; T stands for the number of endogenous variables in the model (Kmenta, 1997).

### Table 4: Result of Endogeneity test (Wu-Hausman Test).

| Crops output | Area Affected by Flood |
|--------------|------------------------|
| Paddy        | 0.048 (0.94)           |
| Jowar        | 63.40 (0.00)           |
| Bajra        | 10.19 (0.01)           |
| Maize        | 5.91 (0.02)            |
| Ragi         | 17.14 (0.00)           |
| Wheat        | 109.45 (0.00)          |
| Barley       | 188.09 (0.00)          |
| Other        | 1.51 (0.22)            |
| Total Cereals | 6.27 (0.01)         |

Sources: Authors Estimation from data collected from 1. Ministry of Agriculture and Farmers’ Welfare, GoI; 2. India Meteorological Department, GoI; 3. Central Water Commission, GoI.

Note: Probability (p) values are in the bracket.
### Table 5: 3SLS estimates of simultaneous equation model.

| Dependent Variable | In Paddy Output | In Wheat Output | In Jowar Output | In Bajra Output | In Maize Output | In Ragi Output | In Barley Output | In Other Cereal and Millets Output | In Total Cereals Output |
|--------------------|-----------------|-----------------|-----------------|-----------------|-----------------|---------------|-----------------|-------------------------------|------------------------|
| lnAr               | 1.011***        | 1.102***        | 0.968***        | 0.986***        | 0.912***        | 0.989***      | 1.085***        | 0.737***                      | 1.014***                |
|                    | (0.057)         | (0.013)         | (0.026)         | (0.023)         | (0.050)         | (0.025)       | (0.036)         | (0.022)                       | (0.034)                |
| lnAa               | -0.007          | -0.485***       | -0.784***       | -0.331**        | -0.423**        | -0.355**      | -0.945***       | -0.085                        | -0.185***               |
|                    | (0.112)         | (0.051)         | (0.145)         | (0.130)         | (0.170)         | (0.174)       | (0.118)         | (0.095)                       | (0.059)                |
| lnFr               | 0.097***        | -0.007          | 0.095**         | 0.008           | -0.071          | 0.187***      | 0.129**         | -0.239***                     | 0.128***               |
|                    | (0.027)         | (0.017)         | (0.046)         | (0.048)         | (0.062)         | (0.040)       | (0.033)         | (0.033)                       | (0.027)                |
| Constant           | -0.514**        | 1.602***        | 1.218**         | 0.710           | 2.677***        | -1.117**      | 1.602***        | 3.099***                      | -0.377***              |
|                    | (0.263)         | (0.192)         | (0.482)         | (0.469)         | (0.686)         | (0.426)       | (0.304)         | (0.337)                       | (0.264)                |
| R Square           | 0.889           | 0.873           | 0.435           | 0.798           | 0.398           | 0.693         | -0.146          | 0.718                         | 0.766                  |

| Dependent Variable: In Affected Area |
|--------------------------------------|
| lnRf                                 | 0.653**         | 0.556**         | 0.268*          | 0.655**         | 0.653**        | 0.502**       | 0.616**         | 0.524**                       | 0.604**                |
|                                     | (0.217)         | (0.159)         | (0.198)         | (0.221)         | (0.202)        | (0.220)       | (0.219)         | (0.222)                       | (0.218)                |
| lnLa                                | 0.195***        | 0.103**         | 0.206***        | 0.196***        | 0.207***       | 0.235***      | 0.132***        | 0.227***                      | 0.172***               |
|                                     | (0.052)         | (0.031)         | (0.051)         | (0.052)         | (0.048)        | (0.046)       | (0.026)         | (0.051)                       | (0.048)                |
| Constant                            | -2.992*         | -1.656          | -0.312          | -3.006**        | -2.989*        | -2.181        | -2.282          | -2.474*                       | -2.474*                |
|                                     | (1.755)         | (1.652)         | (1.384)         | (1.607)         | (1.742)        | (1.685)       | (1.684)         | (1.746)                       | (1.709)                |
| R Square                            | 0.036           | 0.029           | 0.028           | 0.041           | 0.036          | 0.032         | 0.036           | 0.034                         | 0.036                  |

N = 459

Sources: Authors Estimation from data collected from 1. Ministry of Agriculture and Farmers’ Welfare, GoI; 2. India Meteorological Department, GoI; 3. Central Water Commission, GoI

Notes: Area stands for specific crops. *** implies 0.01, ** implies 0.05 and * implies 0.10 level of significance. Standard errors are in parentheses.
system had limited spread of area under coverage of irrigation infrastructure. On the other hand the highly irrigated states viz. Punjab, Rajasthan, Madhya Pradesh and Haryana in terms of average irrigated area have remained least affected by flood whereas the highly flood affected states viz. Assam, Bihar, Odisha reported to have least area under irrigation coverage during the reference period.

CONCLUSION
From the present study it has been found that no doubt expansion of area under cereal crops helped in realisation of higher output, but the spread of area affected by flood led to lowering of cereal crops output level during the reference period. The excessive rainfall to some extent contributed towards occurrence of flood in the selected states. Hence, lower output of cereal crops in the sampled states was largely influenced by area affected by flood where excessive rainfall added fuel to the fire. Exceptionally spread of irrigation contributed towards expansion of area affected by flood, which possibly may be due to the fact that states where irrigation infrastructure being adequate have experienced flood least number of times while the states where flood epidemics was severe, the base and spread of irrigation infrastructure seen to be relatively insufficient. Attention of policymakers towards improving the base and spread of irrigation infrastructure especially in rainfed and flood plain agriculture of Indian states may be instrumental towards minimising the threat of flood on cereal crop output.

Notes
1. India’s total production of cereals was 259.60 million tonne in the year 2017-18 (MAFW, GoI).
2. Indian export of cereal crop was at US$ 8,880.87 million during 2018-19 (Anonymous 2019).
3. Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Haryana, Himachal Pradesh, Karnataka, Manipur, Madhya Pradesh, Punjab, Rajasthan, Tripura, Uttar Pradesh and West Bengal.
4. Rice, wheat, jowar, bajra, maize, barley, other cereals and millets and total cereals.
5. Suitable for over identified equation (Kmenta, 1997).

ACKNOWLEDGEMENT
The authors are thankful to comments and suggestions by Dr. S.M. Jhanwal, Principal Advisor, Department of Agriculture and Cooperation, Ministry of Agriculture, GoI and Prof. Vasant P. Gandhi, IM Ahmadabad during 79th Annual Conference of Indian Society of Agricultural Economics. We acknowledge the financial assistance of UGC in completing the study.

REFERENCES
Anonymous, (2019). Apeda Products - Cereals, Retrieved from http://apeda.gov.in/apedawebsite/six_head_product/cereal.htm, December 10.
Asaduzzaman, M. (1994), The Flood Action Plan in Bangladesh: Some Lessons of Past Investments, Working Paper 94.3, Centre for Development Research (CDR), Denmark.
Banerjee, L. (2010). Effects of Flood on Agricultural Productivity in Bangladesh. Oxford Development Studies. 38: 339-356.
Central Water Commission of India, (2018). State Wise Flood Damage Statistics During 1953 to 2016, Flood Forecasting Directorate, Government of India, New Delhi.
Das, B., and Bora, D. (2020), Determinants of Farm Productivity in Flood Prone area: A Study in Dhemaji District of Assam. Indian Journal of Agricultural Research. 54: 83-88.
Emerick, K., De Janvry, A., Sadoulet, E., Dar, M.H. (2016). Technological innovations, downside risk and the modernisation of agriculture. American Economic Review. 106: 1537-61.
Goyari, P. (2005), Flood Damages and Sustainability of Agriculture in Assam, Economic and Political Weekly. 40: 2723-2729.
Goyari, P. (2014), Irrigation Difference and Productivity Variations in Paddy Cultivation: Field Evidences from Udalguri District of Assam. Indian Journal of Agricultural Economics. 69: 1-18.
Huang, J., Wang, Y., Wang, J. (2015). Farmers’ Adaptation to Extreme Weather Events Through Farm Management and its Impacts on the Mean and Risk of Rice Yield in China. American Journal of Agricultural Economics. 97: 602-617.
Kmenta, J. (1997), Elements of Econometrics, University of Michigan Press, New York.
Mandal, R. (2010), Cropping Patterns and Risk Management in the Flood Plains of Assam, Economic and Political Weekly. 45: 77-81.
Mandal, R. and Bezbarua, M. P. (2013), Diversification of Cropping Pattern: Its Determinants and Role in Flood Affected Agriculture of Assam Plains. Indian Journal of Agricultural Economics. 68: 169-181.
Meena, H.R., Meena, A.S. and Sankhala, G. (2016), Disaster preparedness in Himalayan region: Flood disaster victim perspective. Indian Journal of Agricultural Research. 50: 594-598.
Niles, M.T., Lubell, M., Haden, V.R. (2013), Perceptions and Responses to Climate Policy Risks Among California Farmers. Global Environmental Change, 23: 1752-1760.
Rothenberg, T.J. and Leenders, C.T. (1964). Efficient Estimation of Simultaneous Equation Systems. Econometrica. 32: 57.
Swinnen, J.F., Banerjee, A.N. and De Gorter, H. (2001), Economic Development, Institutional Change and the Political Economy of Agricultural Protection: An Econometric Study of Belgium Since the 19th Century. Agricultural Economics. 26: 25-43.
Theil, H. (1964). Some Developments of Economic Thought in the Netherlands. The American Economic Review. 54: 34-55.
Turkington, D.A. (1985). A Note on Two-Stage Least Squares, Three-Stage Least Squares and Maximum Likelihood Estimation in an Expectations Model. International Economic Review 26: 507-510.
Younus, M.A.F. (2014). Flood Vulnerability and Adaptation to Climate Change in Bangladesh: A Review. Journal of Environmental Assessment Policy and Management. 16: 1-28.
Zelner, A. and Theil, H. (1962), Three-Stage Least Squares: Simultaneous Estimation of Simultaneous Equations. Econometrica. 30: 54-78.