**Supplementary Information**

**Impact of cropping system diversification on productivity and resource use efficiencies of smallholder farmers in south-central Bangladesh: a multi-criteria analysis**

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**Table S1.** Standard coefficients used in this study for calculating energy efficiency parameters and GHG emissions based on agricultural inputs and labor for each system. (1Values are obtained and converted from Lal (2004); 2Values are obtained and converted from IPCC (2006)).

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| a) Energy conversion factors used in this study. | | | | | | | | |
|  | | | | | | | | |
|  |  | | MJ unit-1 | | Source | | | |
| Material inputs | Diesel (L) | | 47.70 | | Pimentel and Pimentel, 2008; Quilty et al., 2014 | | | |
|  | Nitrogen (N kg) | | 66.14 | | Rahman and Hasan, 2014 | | | |
|  | Phosphorus (P2O5 kg) | | 12.44 | | Rahman and Hasan, 2014 | | | |
|  | Potassium (K2O kg) | | 11.15 | | Rahman and Hasan, 2014 | | | |
|  | Seed (kg) | | 15.50 | | Pimentel and Pimentel, 2008 | | | |
|  |  | |  | |  | |  | |
| Human labor | 2-wheel tractor operator (h) | | 0.98 | | Ainsworth et al., 2011; Quilty et al., 2014 | | | |
|  | Hired labor (h) | | 0.98 | | Ainsworth et al., 2011; Quilty et al., 2014 | | | |
|  |  | |  | |  | |  | |
| Seed, Outputs | Rice (kg) | | 15.20 | | Pimentel and Pimentel, 2008 | | | |
|  | Mungbean (kg) | | 14.7 | | Lal et al., 2015 | | | |
|  | Lathyrus (kg) | | 14.7 | | Lal et al., 2015 | | | |
|  | Groundnut (kg) | | 25 | | Nikkhah et al., 2015 | | | |
|  | Chili (kg) | | 0.8 | | Kuswardhani et al., 2013 | | | |
|  | | | | | | | | |
| b) Coefficients for greenhouse gas (GHG) emissions of agricultural inputs | | | | | | | | |
|  | | | | | | | | |
| Emission source | |  | | GHG | | Emission coefficients | | Unit |
| Production, transportation and storage of fertilizers 1 | | Nitrogen (N) | | CO2 | | 4.77 | | Kg CO2e kg-1 N |
| Phosphorus (P2O5) | | CO2 | | 0.73 | | Kg CO2e kg-1 P2O5 |
| Potassium (K2O) | | CO2 | | 0.55 | | Kg CO2e kg-1 K2O |
|  | | | | | | | | |
| Diesel 2 | |  | | CO2 | | 0.0741 | | Kg CO2e MJ-1 |
|  | |  | | CH4 | | 0.000087 | | Kg CO2e MJ-1 |
|  | |  | | N2O | | 0.00887 | | Kg CO2e MJ-1 |
|  | | | | | | | | |
| Direct N2O from N inputs (synthetic fertilizers) in flooded rice field2 | | | | N2O | | 6.33 | | Kg CO2e kg-1 N |
|  | |  | |  |
|  | | | | | | | | |
| Indirect losses of N fertilizer in managed soil 2 | | Leaching or runoff | | N2O | | 1.096 | | Kg CO2e kg-1 N |
| Volatilization and re-deposition | | N2O | | 0.487 | | Kg CO2e kg-1 N |

**Table S2.** Farm-level energy use, costs of production, nutrient use, and hired labor for different cropping systems within and outside polders of south-central Bangladesh (±CI). (1 USD = 77.87 BDT; Letters in columns not separated by solid line indicate differences at alpha=0.05 according to the Tukey’s HSD; Significant code ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Total Energy Production  (GJ ha-1) | Net Energy Yield (GJ ha-1) | Total costs of production (USD ha-1) | Hired Labor (PSD ha-1) | N rate  (kg ha-1) | K2O rate  (kg ha-1) | Wage rate  (BDT PSD-1) | *Aman* Price  (BDT kg-1) |
| a) Within Polders |  |  |  |  |  |  |  |  |
| *Boro –* Fallow *– Aman (BFA)* | 153.95 (9.02) A | 126.76 (8.91) A | 1367.80 (33.88) A | 185.60 (6.70) A | 150.04 (2.12) A | 61.22 (1.51) B | 237.4 (4.4) AB | 20.1 |
| Chili – Fallow *– Aman (CFA)* | 73.24 (6.24) CD | 66.03 (6.16)CD | 1379.34 (23.43) A | 108.64 (4.63) D | 95.80 (1.42) B | 111.89 (1.05) A | 237.8 (3.0) AB | 19.2 |
| Fallow – Fallow *– Aman (FFA)* | 70.40 (1.74) D | 64.89 (1.71) D | 428.97 (6.52) E | 87.88 (1.29) E | 31.18 (0.41) F | 16.45 (0.29) D | 234.6 (0.8) AB | 19.2 |
| Ground nut – Fallow *– Aman (GFA)* | 109.95 (4.51) B | 97.61 (4.46) B | 1073.63 (16.94) B | 133.71 (3.35) B | 48.16 (1.06) C | 37.49 (0.76) C | 237.8 (2.2) A | 19.6 |
| Lathyrus – Fallow – *Aman (LFA)* | 82.25 (2.83) C | 73.80 (2.79) C | 619.44 (10.62) D | 111.02 (2.10) D | 44.60 (0.66) D | 16.23 (0.47) D | 233.0 (1.4) B | 19.0 |
| Mungbean – Fallow – *Aman (MFA)* | 81.00 (1.80) C | 72.81 (1.78) C | 663.06 (6.76) C | 121.49 (1.34) C | 42.73 (0.42) E | 16.49 (0.30) D | 234.6 (0.9) AB | 19.2 |
| *F-value* | 110.86\*\*\* | 69.00\*\*\* | 2430.62\*\*\* | 416.51\*\*\* | 3620.41\*\*\* | 7151.7\*\*\* | 3.76\*\* | NS |
|  | Total Energy Production (GJ ha-1) | Net Energy Yield (GJ ha-1) | Total costs of production (USD ha-1) | Hired Labor (PSD ha-1) | N rate  (kg ha-1) | K2O rate  (kg ha-1) | Wage rate  (BDT PSD-1) | Aman Price  (BDT kg-1) |
| b) Outside polders |  |  |  |  |  |  |  |  |
| *Boro –* Fallow *– Aman (BFA)* | 146.40 (6.63) A | 118.68 (6.51) A | 1355.08 (41.44) A | 183.42 (9.57) A | 153.24 (3.52) A | 60.26 (1.97) A | 228.6 | 18.75 |
| Fallow – Fallow – *Aman (FFA)* | 61.29 (1.91) C | 55.66 (1.88) C | 426.30 (11.96) D | 89.16 (2.76) D | 32.24 (1.02) C | 16.90 (0.57) B | 230.6 | 18.37 |
| Lathyrus – Fallow – *Aman (LFA)* | 72.00 (2.68) B | 63.56 (2.63) B | 605.50 (16.75) C | 110.21 (3.87) C | 44.36 (1.42) B | 16.26 (0.80) B | 231.2 | 18.21 |
| Mungbean – Fallow – *Aman (MFA)* | 71.99 (2.15) B | 63.63 (2.11) B | 654.62 (13.42) B | 122.78 (3.10) B | 44.32 (1.14) B | 17.38 (0.64) B | 230.8 | 18.32 |
| *F-value* | 199.52\*\*\* | 113.31\*\*\* | 704.44\*\*\* | 169.53\*\*\* | 1407.97\*\*\* | 603.08\*\*\* | NS | NS |