Original Research Article

Quadruple cropping patterns in Bangladesh: Scope and limitations

Abstract

Growing crops in a piece of land influence soil fertility depending on adopted management practices and intensity of cropping. Farmers in many cases do not use balanced fertilizers because of socio-economic conditions and thus nutrient mining is inevitable. We hypothesis that soil degradation is likely along with reduced crop productivity in future with proposed four crops production packages. Semi-structured questionnaire, and IDRISI3.2 were used. Net quadruple cropped areas were about 7.09%. Soil fertility scores of those areas were 40–50 and above 50, covering about 4.56% and 3.66%, respectively of the net cropped areas indicating medium fertility status. Apparent nutrient balances for nitrogen, phosphorus, potassium, sulfur, calcium, magnesium and silicon were negative with researcher's introduced cropping patterns and fertilizer management compared to existing patterns. Zinc with all introduced cropping patterns and boron with Potato–Boro–T Aus–T Aman pattern are increasing but other micro nutrients are diminishing. Phosphorus and Sulfur build ups are taking place under farmer's practice in Mustard–Boro–T Aman, Potato–Boro–T Aman and Boro–Fallow–T Aman patterns. Zinc build is taking place under farmer's managed cropping patterns; but iron, copper, boron, molybdenum and chloride are deteriorating from the soils. These indicate that growing four crops in a year with existing fertilizer recommendations are not sustainable in terms of soil fertility. Adoption of such intensive crop culture by the majority of the farmers is unlikely except in some sporadic areas having market driven economy of vegetable cultivation.

Key words: Nutrient balance, rice, soil fertility, vegetables, wheat

1. Introduction

There are many crop growing niches in Bangladesh, which is determined by climate, environment, resources and socioeconomic conditions of the farmers. Growing crops in a sequence is an annual strategy to optimize agronomic and economic yields in a sustainable manner (Nasim et al. 2017) and commonly known as cropping pattern (CP). Crop diversity, input use, management, weed and disease infestation, soil bulk density, cover crop, green manure, mulches, organic matter, erosion, water infiltration, and so on are influenced by CP.

Construction of houses, roads and industrial infrastructures to support increased population in the country are responsible for losses of cultivable land; while on the other hand, growing more crops yearly from a land are placing tremendous pressures on soil productivity. Among many crops grown, most patterns are rice and wheat based (Sheikh et al. 2009; Islam et al. 2007) in which rice-rice or rice-wheat are dominant (Prasad et al. 2002). Such scenarios are changing because of increased food demand and availability of short duration varieties of rice, mustard and mungbean that allow the farmers to grow three or more crops in the same land in a year (Mondal et al. 2015).

Mustard, mungbean and rice, the primitive crops in Bangladesh, fulfill domestic demands for nutrition (Sheikh et al. 2009); but intensive rice based cropping causes soil nutrient depletion in many cases (Hasan et al. 2003; Chitdeshwari et al. 2011). Farmers generally use imbalanced fertilizer doses on a single crop basis (Kabir et al. 2002) and thus either nutrient mining (Panaullah et al. 2006; Saha et al. 2016; Mamathashree et al. 2017) or build up takes place (Quddus et al. 2017a). Moreover, losses of nutrients through leaching, erosion and emission are also responsible for soil fertility depletion (Yu et al. 2014; Padre et al. 2007). Under such situations, growing legumes in between cereals and oilseeds and balanced use of fertilizers along with integrated nutrient management can contribute in maintaining soil fertility (Islam et al. 2013; Stagnari et al. 2017) and in improving crop yields (Rundala et al. 2013; Singh et al. 2014).

Study on nutrient balance is important for assessing its fate from added and soil reserves (Blaise et al. 2005; Phong et al. 2011) that also helps in quantifying fertilizer requirements for yield maximization (Paul et al. 2014; Bindraban et al. 2000). As the cropping intensity is increasing to feed ever growing populations, it is essential to quantify the fate of soil fertility if four crops are grown in a year for sustained crop production. We have tested the hypothesis that soil degradation is likely along with reduced crop productivity in future with proposed four crops production packages by the national agricultural research institutes.

2. Materials and Method

2.1. Data collection

The study was conducted during 2014 to 2016 throughout the whole country. A semi-structured questionnaire was used for data collection on crops, cropping pattern (CP) and its area coverage. Initially, a small team of investigators collected data for each Upazila (a small administrative unit of a district) from the office of the Deputy Director (DD), department of agricultural extension (DAE) and then the questionnaire was distributed to Upazila Agriculture Officers, DAE for the above mentioned data collection. Data from DD offices and Upazila Agriculture offices were analyzed to find out mismatch in data, if any. After initial analyses, stakeholder consultation workshops were conducted in 64 districts of Bangladesh. A team of researchers, DD and district level officers of DAE and officers from Upazila Agriculture Offices were present in the workshops for finalizing data recording. Quadruple cropping areas were recorded when four crops in a year were grown sequentially and net cropped area was the summation of cultivated areas of a region. Dominant three and two crops patterns such as Mustard–Boro–T. Aman, Potato–Boro–T. Aman and Boro–Fallow–T. Taman were selected based on area coverages for comparison of nutrient balances.

2.2. Fertilizer dose and apparent nutrient balance

Recommended fertilizer doses were considered for growing different crops as stated by fertilizer recommendation guide-2018 (Ahmed et al. 2018). Above ground biomass of selected crops were considered for determination of total nutrient uptakes in a year, which were computed based on available literatures (FAO 2006, 2018; Tandon 2004; Aulakh 1985; Yara 2019; Quddus et al. 2017). Nutrient concentrations in rain and irrigation water were taken according to Quddus et al. (2017b) and Biswas et al. (2018). A total nutrient input received by a specific pattern was the summation of indigenous soil nutrients, added fertilizer nutrients and nutrients added through rain and irrigation water. Apparent nutrient balance (ANB) was computed as follows:

ANB = (Yearly total nutrient input) – (Total nutrients removed by all crops)

2.3. Scoring of soil parameters

Data on soil organic carbon (SOC), available P, S, Zn, B, cation exchange capacity (CEC), soil pH and exchangeable K were collected from Bangladesh Agricultural Research Council website, Soil Resource Development Institute. Soil nutrient status in Bangladesh has been classified as very low, low, medium, optimum and high based on different ranges (FRG 2018). This classification system was considered for assigning scoring (0 -100 scale) values as 5, 30, 70, 100 and 100 for very low, low, medium, optimum and high fertility status, respectively against each selected soil attributes. The least score was assigned to the lowest nutrient status and SOC content.

2.4. Soil fertility rating and map preparation

Attribute-wise soil fertility ratings for target areas were made by using MS-Excel Macros and IDRISI3.2. Soil fertility rating maps were prepared based on arithmetic mean (AM), weighted mean (WM) and geometric mean (GM) scores. Among soil attributes the most limiting factors dictate crop yield, so we have provided weight to such factors in determining WM score as follows:

$$WM = ([SOC_{score}]*[P_{score}]*[K_{score}]*[CEC_{score}]*[pH_{score}])^{\wedge}(1/5)*0.5 + [S_{score}]*0.25 + ([Zn_{score}]*[B_{sore}])^{\wedge}(1/2)*0.25$$

$$AM = ([B_{csore}]+[K_{score}]+[P_{score}]+[CEC_{score}]+[pH_{score}]+[SOC_{score}]+[S_{score}]+[Zn_{score}])/8$$

Where, SOC_{score} is the soil organic carbon, P_{score}, K_{score}, S_{score}, Zn_{score} and B_{score} stand for phosphorus, potassium, sulphur, zinc and boron scores, respectively.

2.5. Determination of crop-field duration

Field duration of four crops pattern were determined based on Bangladesh Agricultural Research Institute and Bangladesh Rice Research Institute documents. Seedling ages in days for Boro, T. Aus and T. Aman rice considered were 40, 25 and 30 days respectively.

3. Results

3.1. Distribution of major four crops pattern

Among 11 four-crops cropping patterns (Fig. 1), Mustard–Boro (irrigated dry season rice)–Aus (pre-monsoon rice)–T. Aman (wet season rainfed rice) was dominant (7850 ha) followed by Potato–Boro–Aus–T Aman (3140 ha), Mustard–Boro–Jute–T Aman (2980 ha), Potato–Boro–Jute–T Aman (2160 ha), Potato–Maize–Aus–Vegetable (1030 ha) and Vegetable–Boro–Aus–T Aman (820 ha). Cucurbits, snake-gourd, gima kalmi (*Ipomoea* Sp), cabbage and potato were the vegetables crops. Mustard–Boro–Aus–T Aman pattern was distributed in north-west, south-west, central and central-east part (Fig. 2a); Potato–Boro–T Aus–T Aman pattern mainly in north-west south-east regions (Fig. 2b); Mustard–Boro–Jute–T Aman in northern, central and south-west part (Fig. 2c); Potato–Boro–Jute–T Aman and Potato–Maize–Aus–Vegetable in north-western part (Fig. 2d & e), and Vegetable–Boro–Aus–T Aman in north-west and south-east regions of the country.

3.2. Net four crops cropping pattern and soil fertility

Net four cropped areas were distributed in north-west, north, central-west and central east regions of the country (Fig. 3a). In terms of net areas, <50 ha, 50−100 ha, 100−500 ha and 500−2500 ha were covered by four crops in 2.03%, 2.13%, 1.93% and 1.0% areas of the country, respectively. Fertility scores in those areas varied from <40 to >55 (Fig. 3b) of which about

4.56% areas belong to 40-50 score category and above 50 score in about 3.66% areas of the country.

3.3. Apparent nutrient balance

In four crops cropping patterns under researcher's management, apparent nutrient balances for N, P, K, S, Ca, Mg, Mn and Si were negative in Mustard–Boro–T Aus–T Aman, Potato–Boro–T Aus–T Aman, Mustard–Mungbean–T Aus–T Aman and Potato–Mungbean–T Aus–T Aman patterns (Fig. 4a). While on the other hand, P and S build ups are taking place under farmer's practice in Mustard–Boro–T Aman, Potato–Boro–T Aman and Boro–T Aman patterns (Fig. 4b). Zinc with all introduced cropping patterns and B with Potato–Boro–T Aus–T Aman patter are increasing but Fe, Cu, Mo and Cl are diminishing (Fig. 5a). However, with farmer's managed cropping patterns, Zn build is taking place; but Fe, Cu, B, Mo and Cl are mining from soil (Fig. 5b).

4. Discussion

Food demands in Bangladesh are increasing and thus compelling the researchers in adopting different steps to improve its production. Introduction of four crops is one of those efforts for increasing cropping intensity and thus improving total food production that have found in some areas (Fig. 3a) because of suitable soil types and marketing demands. Such patterns are mostly prevalent in areas having light textured soils. Growing four crops in a year from the same piece of land is challenging in many aspects such as preparing the land at the right time, irrigating the crops, use of balanced fertilizers, increased natural calamities, etc. Besides, growing four crops in a sequence leaves only a few days in between harvesting one crop and planting/seeding of the next one. Depending on availability of crop varieties, total field duration requirements would be about 300-355 days for four crops patterns (Table 1) making it difficult for the conventional farmers to accomplish all jobs to be done at the right time. Sometimes growing short duration rice varieties in T. Aman (monsoon rice) season is not helpful to accommodate winter season crops at the right time because of late heavy rains that are frequently taking place now-a-day under changing climate. Rate damages with early matured rice crops also discourage farmers to grow short duration rice varieties in many cases. Moreover, crop growing areas are decreasing because of infrastructure development and industrialization. Yearly shifting of agricultural land to non-agricultural use is about 1% (Hossain et al. 2017).

As indigenous soil fertility play an important role in sustainable crop production along with added fertilizer management, recuperating soil fertility is very much essential. Among the tested four-crops cropping patterns, apparent balances of major and micro nutrients were negative except Zn and B with introduced cropping patterns even with researcher's fertilizers recommendation. A few examples are provided herewith. Hossain et al. (2018) reported negative N and K balances even with legume based four-crops cropping pattern (Lentil–Mungbean–T Aus– T Aman). Negative balances even after NPK application with wheat–rice and maize–rice patterns were reported by Salam et al. (2014). Such depletions of nutrients are strongly related with yield reduction (Haque et al. 2014). In most cases, micronutrients are not added adequately along with minimum or no use of organic nutrient sources. Besides, marketing of adulterated fertilizers and its use by the farmers are also playing a negative role in maintaining soil fertility (Mohiuddin et al. 2017). This clearly indicates that soil productivity will decline in near future with such high cropping intensity in Bangladesh. Building up or mining of any nutrient is responsible for disrupting nutrient ratios in soil-plant system and thus impairs growth and development of crop plants resulting in uneconomic harvest.

Soil degradation, especially in terms of fertility is a major cause of yield stagnation or its declining trends in some countries including Bangladesh. The estimated average depletion of N, P_2O_5 and K_2O was about 50 kg yr^{-1} in 2000 (FAO 2006). About 52% soil samples were Ca deficient in agro-ecological zone (AEZ)-3 and 4% in AEZ-21 (Saha et al. 2016). We may face a dire consequence of not being able to produce enough to feed our peoples even with high inputs. There are some hopes if we can recycle decomposable wastes for crop production. For example, P recovery from city wastes varies from 10-80% depending on capacity of the recycling systems

(FAO 2006). Moreover, adoption of precision agriculture, mechanization and market driven policy might alleviate nutrient depletion problems in intensive cropping zones of the world.

5. Conclusions

Variable cropping patterns are existed in Bangladesh in which rice-based patterns are dominant. Through the efforts of researchers and extension personnel, areas under four-crops cropping patterns are increasing. Among 11 four-crops cropping patterns tested, Mustard–Boro–Aus–T Aman was dominant, although net quadruple crop areas were only 7.09%. Apparent nutrient balances for most studied nutrients were negative with researcher's introduced cropping patterns and fertilizer management. Zinc with all introduced cropping patterns and B with Potato–Boro–T Aus–T Aman pattern are increasing but Fe, Cu, Mo and Cl were diminishing. Phosphorus, Zn and S build ups were taking place under farmer's practice in some cases indicating that tuning up of P, Zn and S fertilizer doses need to be done; but Fe, Cu, B, Mo and Cl were deteriorating from the soils. These indicate that growing four crops in a year with existing fertilizer recommendations are not sustainable in terms of soil fertility.

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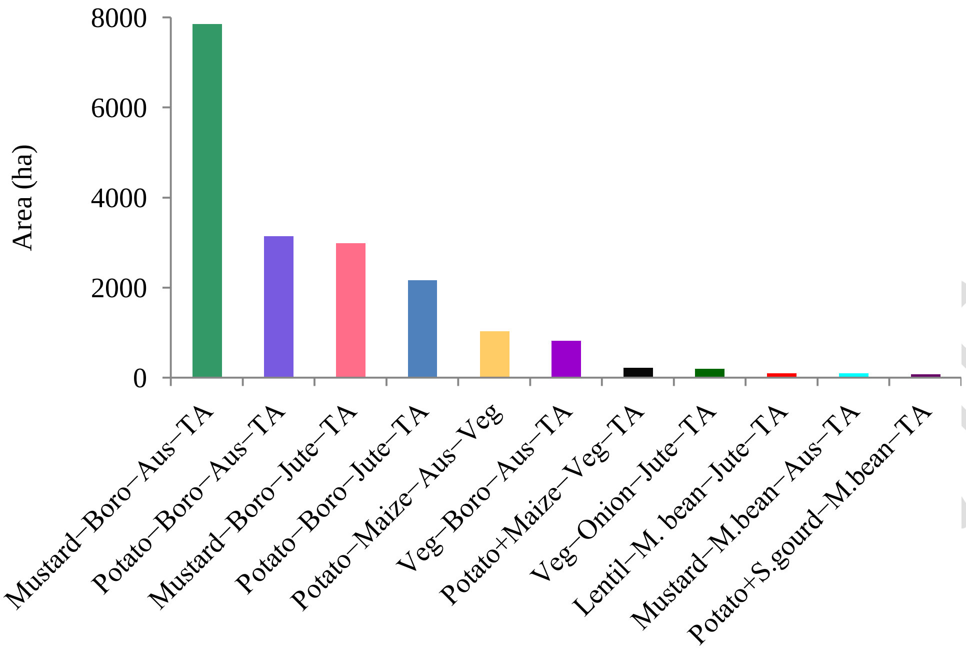

Fig. 1. Area coverage by four crops cropping patterns in Bangladesh; Veg = Vegetable, TA = T Aman, S.gourd = Sweet gourd, M.bean = Mungbean

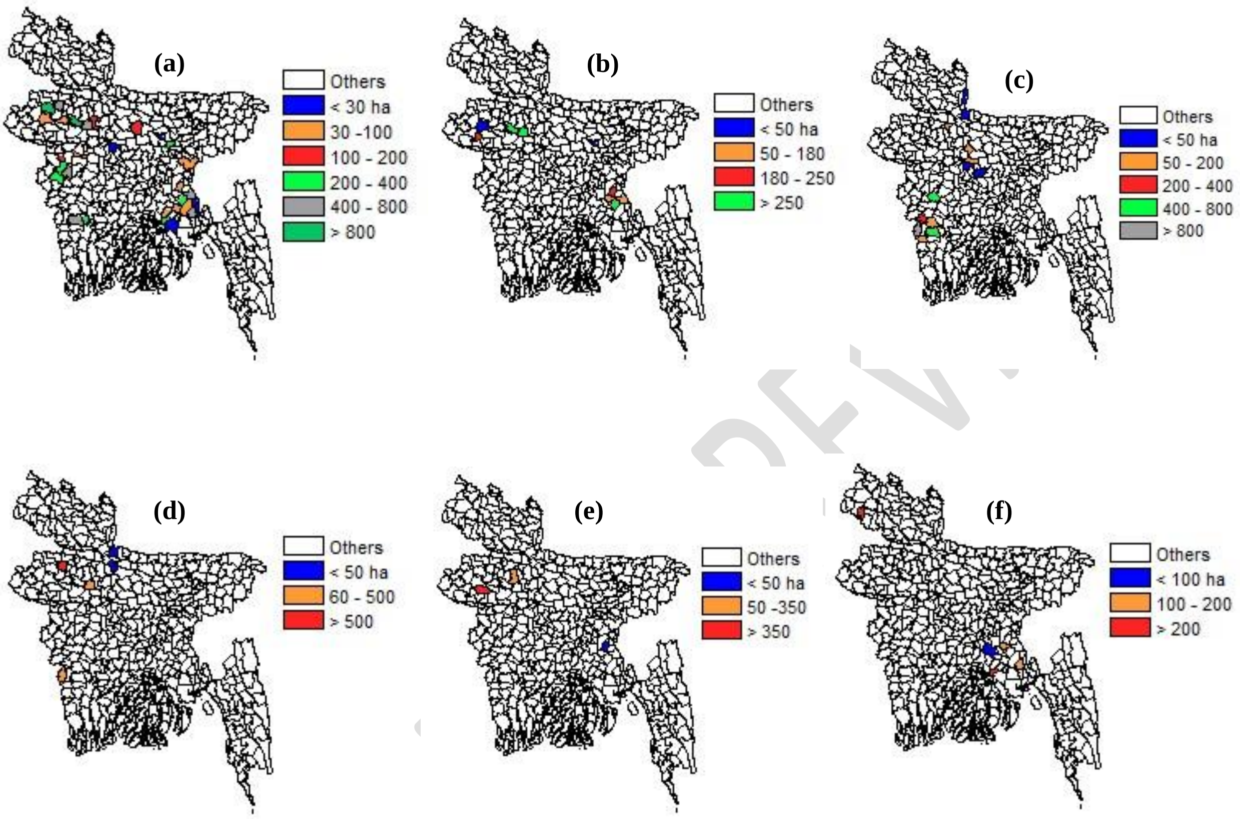

Fig. 2. Area distribution of (a) Mustard-Boro-T Aus-T Aman, (b) Potato–Boro–T Aus–T Aman, (c) Mustard–Boro–Jute–T Aman, (d) Potato–Boro–Jute–T Aman, (e) Potato–Maize–Aus–Vegetable, (f) Vegetable–Boro–T Aus–T Aman patterns in Bangladesh

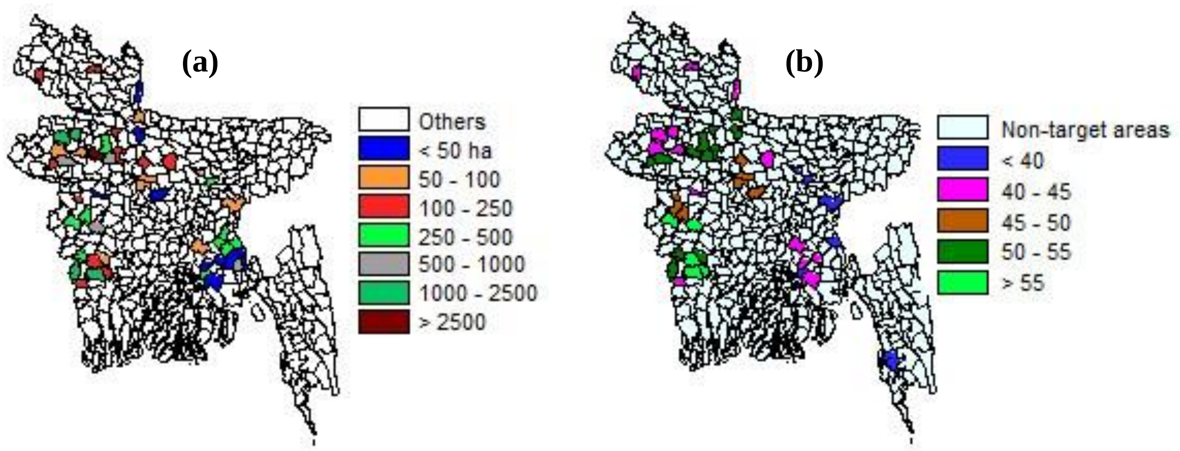

Fig. 3. Distribution of (a) net four cropped areas and (b) soil fertility score in four crops growing areas in Bangladesh

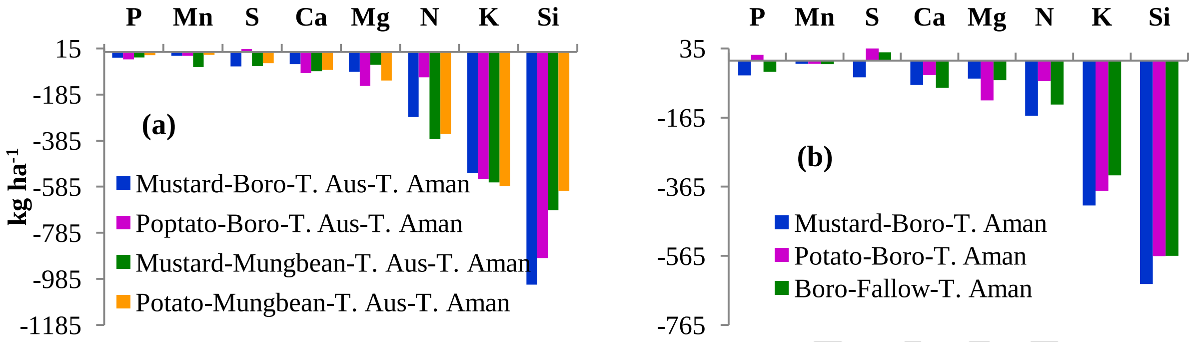

Fig. 4. Apparent nutrient balances in (a) researcher's and (b) farmer's fertilizer management under different cropping patterns in Bangladesh

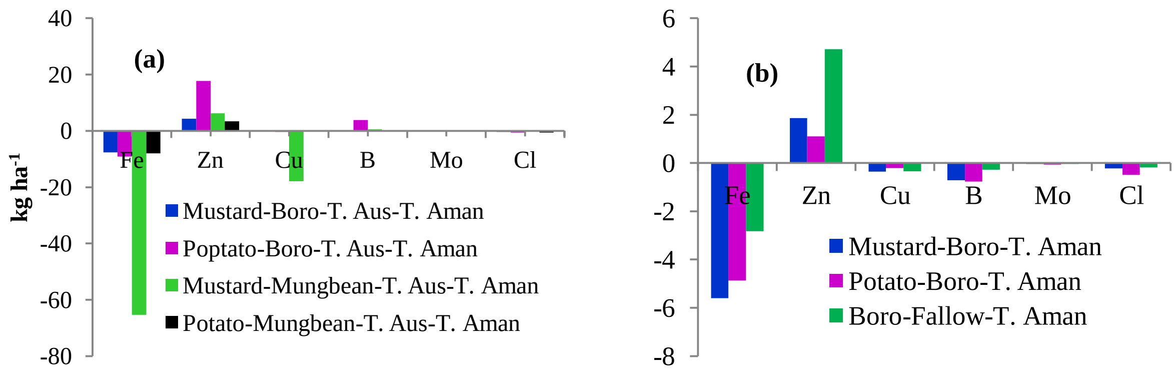

Fig. 5. Apparent micronutrients balance in (a) researcher's and (b) farmer's fertilizer management under different cropping patterns in Bangladesh.

Table 1. Minimum field durations required for growing four crops in a year

Proposed patterns	Field duration (days)
Mustard-Boro-T. Aus-T. Aman	345-355
Potato-Boro-T. Aus-T. Aman	350-355
Mustard-Mungbean-T. Aus-T. Aman	300-310
Potato-Mungbean-T. Aus-T. Aman	315-325