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Can Crop Productivity be Predicted by Soil Characterization After Land Leveling?

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Abstract

Land leveling is a common agricultural practice in the mid-southern United States to facilitate uniform distribution of irrigation water. However, land leveling is also a severe form of soil disturbance that often results in decreased productivity. Information on correlations between post-leveling soil properties and crop production parameters, especially yield, can facilitate improved crop management. The objective of this study was to determine whether soybean (*Glycine max* (L.) Merr.) and rice (*Oryza sativa* L.) productivity could be predicted from a comprehensive characterization of soil physical, chemical, and biological properties, including those provided in typical routine soil analyses, immediately following shallow land leveling. Despite numerous significant correlations between crop production parameters and post-leveling soil properties, results indicate that a relatively comprehensive assessment of post-leveling soil surface properties is of little value for predicting first-year soybean and/or second-year rice response. Further research is needed to ascertain the factors other than those measured in this study that are responsible for controlling soybean and rice response following shallow land-leveling activities.

Introduction

Fig. 1. Typical land-leveling activities in the mid-southern United States. Photo taken by Russ DeLong.

Land leveling is a common agricultural practice in the mid-southern United States to facilitate uniform distribution of irrigation water and to maintain uniform soil moisture conditions (1) (Fig. 1). Land leveling is routinely performed in fields where irrigated crops will be grown, such as rice (*Oryza sativa* L.) and soybean (*Glycine max* (L.) Merr.). However, many have reported a decline in soil fertility coupled with reduced crop productivity as a result of land leveling. Deficiencies in essential plant nutrients (e.g., N, P, and K) can limit crop growth following land leveling (2,3,4,5). Exposing the subsoil can also result in major changes in surface soil pH, decreased organic carbon, and exposure of Na-rich sodic horizons (6).

In the mid-southern United States, rice is typically grown in the first year following land leveling because the flooded soil environment can facilitate uniform nutrient distribution and therefore enhance nutrient availability. In addition, the fibrous root system of rice has a large surface area for nutrient uptake in the disturbed soil following land leveling. In contrast, to maintain a crop rotation, soybean may be grown immediately after land leveling. However, soybean is known to be more sensitive than rice to disturbed soil conditions and altered soil fertility. This presents potential management difficulties with a first-year soybean crop following land leveling because significant alteration of the magnitudes and spatial distributions of soil physical, chemical, and biological properties can occur after even relatively shallow land-leveling activities (7,8,9,10). A potential complication for management of a first-year soybean crop following land leveling is that soybean growth and yield have been shown to be responsive to a wide variety of stimuli that are directly related to soil physical and chemical properties. Therefore, it may be difficult to determine and address potential yield-limiting factors prior to planting immediately following land leveling. In addition, it may be equally difficult to begin managing a newly land-leveled field to restore its pre-leveling productivity (2) without a comprehensive characterization of soil physical, chemical, and biological properties immediately following land leveling, but prior to planting the initial post-leveling crop. Routine soil analyses, consisting of pH, electrical conductivity (EC), extractable nutrient concentrations, and sometimes organic matter (OM), offer the easiest and most convenient method for many producers to gain insight into post-leveling soil properties, but whether a routine soil analysis provides the right information to predict crop response following leveling is uncertain.

The objective of this study was to determine whether soybean and rice production can be predicted from a comprehensive characterization of soil physical, chemical, and biological properties, including those provided in typical routine soil analyses, following shallow land leveling. We hypothesized that total above-ground dry matter production, seed yield, and harvest index of soybean as the first crop and of rice as the second crop following shallow land leveling would be significantly correlated with post-leveling soil properties. Specifically, it was hypothesized that areas with relatively high soil bulk density (i.e., compacted areas) following land leveling would correspond to areas of relatively low dry matter production and yield. In contrast, areas with relatively high microbial biomass, organic matter, extractable nutrients following land leveling would correspond to areas of relatively high dry matter production and yield. Although land leveling is a prominent water-conservation practice in the mid-southern United States, previous studies have shown a general trend of reduced yields following land leveling. Accordingly, determining post-leveling soil parameters that significantly correlate to future crop productivity could be useful to help improve crop management strategies, maintain high-yielding, productive land, and, ultimately, increase profitability.

Site Description and Experimental Design

The study area was located within a 5-ha land-leveled area of an approximately 25-ha field predominantly cropped to rice and soybean in Arkansas County, Arkansas (34°6'N, 91°22'W). The soil was a Stuttgart silt loam (fine, smectitic, superactive, thermic Albaqultic Hapludalf; 11) that formed in silty and clayey alluvium and is a very deep, moderately well to somewhat poorly drained, slowly permeable soil. During the growing season prior to land leveling, the field containing the study area was in rice production and, up until the land leveling occurred, was gently rolling with a 1-to-2% slope. The soil and physiographic field conditions of this study typify a significant land area in the Mississippi Delta region of eastern Arkansas, as well as eastern Louisiana and western Mississippi, that is dominated by rice production.

Prior to land leveling, a 40-×-90-m sampling grid (0.36 ha) was established as the study area within approximately 5 ha that was to be land leveled. Grid points (i.e., sampling points) were spaced evenly 10-m apart, for a total of 50 grid points.

Field Manipulations

Land leveling occurred at the site in early-April 2002 resulting in a uniform 0.2% slope throughout the study area. After initial cutting and filling were completed, the entire area was re-graded to eliminate minor topographic variations. During the re-grading process, some soil originally removed from the cut area was pushed from the filled area back onto the cut area. The maximum depth of cut was roughly 15 cm throughout the 0.36-ha study area.

In late-May 2002, the soybean cultivar Armor 54-Z4 (conventional maturity group 5) was seeded into soil with adequate moisture with a row spacing of 76 cm and a seeding rate of 63 kg/ha (1 bu/acre). The field was fertilized according to University of Arkansas recommendations with P_2O_5 at approximately 45 kg/ha and K_2O at 67 kg/ha. The soybean crop was flood irrigated on an as-needed basis approximately three times throughout the growing season.

In mid-April 2003, the study area was disked multiple times followed by land planing to prepare the seedbed. Rice was drill-seeded at a row spacing of 19 cm at a 110 kg/ha (100 bu/acre) seeding rate. The field was fertilized according to University of Arkansas recommendations with N at 135 kg/ha, P_2O_5 at 67 kg/ha, K_2O at 67 kg/ha, and 0.22 kg seed-treated Zn per 100-wt of seed. The permanent flood was established in early June when the plants reached the five-leaf stage.

Soil Sampling and Analyses

On 9 May 2002, approximately 3 weeks after land leveling, three sets of soil samples were collected from the top 10 cm within a 20-cm radius surrounding each grid point for physical (i.e., bulk density and particle-size distribution), chemical (i.e., extractable nutrients, pH, electrical conductivity, and organic matter), and biological (i.e., fungal and bacterial biomass concentrations) property determination. The 0- to 10-cm depth was sampled because the top 10 cm of soil represents the majority of the root zone for rice and for soybean grown in rotation with rice in Arkansas and much of the Mississippi Delta region of the mid-South, due to the widespread occurrence of a hard pan near the 10-cm depth.

One set of soil samples consisted of a single 4.8-cm diameter soil core collected at each grid point with a slide hammer, oven dried at 70°C for 48 hr, and weighed for bulk density (BD) determination. The soil-core sampling chamber was beveled to the outside to minimize compaction upon sampling. Oven-dry soil was subsequently crushed and sieved to pass a 2-mm mesh screen for particle-size analysis using the hydrometer method (12).

A second set of soil samples consisted of ten 2-cm diameter soil cores that were collected from each grid point, combined into a composite sample, oven dried at 70°C for 48 hr, crushed, and sieved to pass a 2-mm mesh screen for soil chemical analyses. Dried and sieved soil was extracted with Mehlich-3 extractant (13) in a 1:10 (w/v) soil-to-extractant-solution ratio and analyzed for extractable nutrients (i.e., P, K, Ca, Mg, Na, S, Fe, Mn, Zn, Cu, and B) using an inductively coupled argon-plasma spectrophotometer (CIROS CCD model, Spectro Analytical Instruments, MA). Soil pH and EC were determined with an electrode on a 1:2 (w/v) soil-to-water solution. Organic matter was determined on sieved soil by weight-loss-on-ignition after 2 hr at 360°C (14). Many of these analyses constitute a routine soil analysis that is available for producers. In Arkansas specifically, pH, EC, and the suite of Mehlich-3 extractable nutrients constitutes a routine soil analysis that is free-of-charge for producers who submit samples through their county extension agent.

A third set of soil samples consisted of an additional set of ten 2-cm diameter soil cores collected and combined into a composite sample from each grid point. Samples were kept in a cooler in the field and stored at 4°C for microbial biomass determination. A dilution series was prepared from fresh soil samples and aliquots removed for bacterial and fungal agar-plate counts. Total fungal (15) and bacterial biomass (16) concentrations were estimated by epi-fluorescent microscopy and sample staining.

Extractable soil nutrients and bacterial and fungal biomass are expressed on a mass-per-area basis following conversion from concentration using the measured soil BD values.

Plant Sampling

In order to obtain plant data that would represent a response from soil properties at discrete grid point locations, a 1-m row of all above-ground biomass straddling each grid point was harvested by hand at physiological maturity in 2002 (soybean) and 2003 (rice). This approach of harvesting relatively small segments of row is common practice in small-plot work with rice, but is not the standard procedure with most other crops. However, we felt that it was necessary to remain consistent with plant sampling procedures across crops. Furthermore, employing a more standard approach of determining yield by harvesting longer lengths of row would have resulted in a plant response that would likely have been unrepresentative of the soil properties at the discrete grid point locations.

Harvested plant samples were air dried for 10 days at approximately 24°C, oven dried at 70°C for 48 hr, and weighed for above-ground dry matter (DM) determination. For the 2002 soybean crop, plant samples were subsequently mechanically thrashed to separate seeds from the vegetative portion of the samples. The seeds were collected, weighed, and oven-dry seed weights were adjusted to 13% moisture by weight. For the 2003 rice crop, all panicles from the plant sample were removed from the straw at the upper-most node and both the straw and panicles were weighed. The panicle weight was used to represent the rice yield. Harvest index (HI) was calculated for soybean and rice as the ratio of the seed mass to the mass of total above-ground DM.

Statistical Analyses

To test whether post-leveling soil properties can predict subsequent crop production, linear correlations were performed and multiple regression analyses were conducted between total above-ground DM, seed yield, and HI and post-leveling soil physical, chemical, and biological properties (Minitab 13.31, Minitab Inc., State College, PA).

Crop Production Following Land Leveling

In 2002, soybean was the first crop grown immediately following shallow land leveling to maintain the prior crop rotation sequence. Soybean above-ground DM production varied widely from 0.7 to 8.6 Mg/ha with a coefficient of variation (CV) of 43.7% and averaged 4.4 [standard error (SE) = 0.3] Mg/ha throughout the study area. Soybean seed yield varied from 0.4 to 3.5 Mg/ha with a CV of 42.4% and averaged 1.81 (SE = 0.1) Mg/ha. Variations in soybean DM and yield were consistently high or low for each sample, such that soybean HI was less variable than DM and yield, ranging from 0.25 to 0.69 with a CV of 20.2%. Soybean HI averaged 0.43 (SE = 0.01) throughout the study area in 2002.

In 2003, rice was the second crop grown following shallow land leveling. The second-year rice crop produced considerably less variable and more above-ground DM than the previous soybean crop. Rice above-ground DM production varied from 4.1 to 25.3 Mg/ha with a CV of 23.0% and averaged 16.8 (SE = 0.6) Mg/ha throughout the study area. Similar to the relationship between soybean DM and yield variability, rice seed yield varied as much as DM, ranging from 2.1 to 12.4 Mg/ha with a CV of 23.2% and averaged 8.5 (SE = 0.3) Mg/ha. Similar to soybean HI, rice HI was much less variable than rice DM and yield, ranging from 0.43 to 0.57 with a CV of 5.8%. Rice HI averaged 0.51 (SE $<$ 0.01) throughout the study area in 2003.

Detailed spatial statistical analyses for first-year soybean production parameters and their spatial correlation with soil properties are reported by Brye et al. (9), therefore they are not discussed here. Similarly, detailed spatial statistical analyses of the effects of land leveling on soil physical, chemical, and biological properties are reported by Brye et al. (7,8), therefore they are not discussed here.

Crop Production Parameter Correlations with Post-leveling Soil Properties

As hypothesized, soybean production parameters correlated with post-leveling, pre-plant soil properties (Tables 1 and 2). Soybean above-ground DM was significantly ($P < 0.05$) positively correlated with 0 to 10 cm organic matter, Mehlich-3 extractable P, Ca, Fe, Mn, Cu, and Zn, bacterial and fungal biomass, and fungal-to-bacterial biomass ratio ($0.28 < r < 0.49$). It appears that, after land leveling, soil chemical and biological properties become crucial in improving soybean growth and production. However, soybean above-ground DM did not correlate with any soil physical properties assessed in this study (i.e., bulk density, sand, silt, and clay content). Similar to above-ground DM, soybean seed yield was significantly ($P < 0.05$) positively correlated with 0 to 10 cm Mehlich-3 extractable Zn, bacterial and fungal biomass, fungal-to-bacterial biomass ratio, and soil pH ($0.30 < r < 0.50$). In contrast to above-ground DM and seed yield, soybean HI was significantly ($P < 0.05$) negatively correlated with 0 to 10 cm sand content, EC, organic matter, Mehlich-3 extractable P, Ca, Mg, Fe, Mn, Cu, Zn, and B ($-0.32 < r < -0.40$), and significantly ($P < 0.05$) positively correlated with 0 to 10 cm BD (r = 0.41) and clay content (r = 0.33). Apparently, some or all of these soil nutrients contributed significantly to vegetative growth, but not to seed yield, resulting in lower HI. Soybean HI did not correlate with any biological properties despite both above-ground DM and seed yield being significantly positively correlated with all three biological properties assessed in this study.

Table 1. Summary of pre-plant soil physical, chemical, and biological properties following land leveling in eastern Arkansas. Data complied from Brye et al. (7,8).

Post-leveling soil property	Mean	Range
Physical	r	
Bulk density (g/cm^3)	1.29	1.15 - 1.44
Sand (kg/kg)	0.13	0.09 - 0.17
Silt (kg/kg)	0.71	0.64 - 0.83
Clay (kg/kg)	0.16	0.04 - 0.23
Chemical		
pH	7.6	6.0 - 8.1
Electrical conductivity (dS/m)	0.16	0.09 - 0.23
Organic matter (g/kg)	18.5	14.0 - 21.0
Extractable P (kg/ha)	33.1	15.6 - 49.0
Extractable K (kg/ha)	180	107 - 281
Extractable Ca (kg/ha)	2704	1455 - 3630
Extractable Mg (kg/ha)	416	284 - 500
Extractable Na (kg/ha)	218	142 - 320
Extractable S (kg/ha)	41.9	28.4 - 78.8
Extractable Fe (kg/ha)	339	127 - 511
Extractable Mn (kg/ha)	361	102 - 462
Extractable Cu (kg/ha)	4.0	2.4 - 5.1
Extractable Zn (kg/ha)	8.8	3.6 - 12.3
Extractable B (kg/ha)	1.8	0.8 - 16.7
Biological		
Bacterial biomass (g/m^2)	16.8	6.3 - 23.8
Fungal biomass (g/m^2)	10.2	1.2 - 25.7
Fungal-to-bacterial biomass ratio	0.68	0.10 - 2.8

Table 2. Correlations (r) among post-leveling soil physical, chemical, and biological properties and soybean production parameters as the first crop following land leveling in eastern Arkansas. Data taken from Brye et al. (9).

Post-leveling soil property	**Dry matter** (Mg/ha)	**Seed yield** (Mg/ha)	**Harvest index**
Physical		**r**	
Bulk density (g/cm^3)	- 0.033	0.129	0.411**
Sand (kg/kg)	0.119	- 0.010	- 0.323*
Silt (kg/kg)	0.168	0.099	- 0.181
Clay (kg/kg)	- 0.227	- 0.096	0.333*
Chemical			
pH	0.107	0.430**	- 0.084
Electrical conductivity (dS/m)	0.243	- 0.046	- 0.332*
Organic matter (g/kg)	0.374**	0.132	- 0.330*
Extractable P (kg/ha)	0.343*	0.265	- 0.348*
Extractable K (kg/ha)	0.208	0.173	- 0.223
Extractable Ca (kg/ha)	0.302*	0.171	- 0.341*
Extractable Mg (kg/ha)	0.171	0.038	- 0.355*
Extractable Na (kg/ha)	- 0.190	- 0.251	0.002
Extractable S (kg/ha)	- 0.141	- 0.080	0.150
Extractable Fe (kg/ha)	0.381**	0.258	- 0.341*
Extractable Mn (kg/ha)	0.283*	0.157	- 0.385**
Extractable Cu (kg/ha)	0.359**	0.216	- 0.399**
Extractable Zn (kg/ha)	0.382**	0.299*	- 0.354*
Extractable B (kg/ha)	0.221	0.114	- 0.326*
Biological			
Bacterial biomass (g/m^2)	0.484***	0.497***	- 0.065
Fungal biomass (g/m^2)	0.490***	0.490***	- 0.089
Fungal-to-bacterial biomass ratio	0.466***	0.421***	- 0.143

* Significant at $0.01 < P \leq 0.05$; ** Significant at $0.001 < P \leq 0.01$;
*** Significant at $P \leq 0.001$.

In contrast to that which was hypothesized, post-leveling, pre-plant soil properties (i.e., physical, chemical, and biological) did not correlate with above-ground DM or seed yield of the second-year rice crop (Table 3). This result is similar to that of Walker et al. (10) who concluded that rice yield reduction following land leveling was more related to the volume of cut soil than to changes in soil fertility. This might be due to the fact that the flooded-soil conditions in the rice field may have increased uniformity of nutrient availability in nutrient rich and poor areas. However, rice HI was significantly ($P < 0.01$) negatively correlated with bacterial and fungal biomass and fungal-to-bacterial biomass ratio (- 0.33 < r < - 0.48), indicating that as soil biological parameters increased, rice HI tended to decrease (Table 3).

Table 3. Correlations (r) among post-leveling soil physical, chemical, and biological properties and rice production parameters as the second crop following land leveling in eastern Arkansas.

Post-leveling soil property	**Dry matter** (Mg/ha)	**Panicle yield** (Mg/ha)	**Harvest index**
Physical		**r**	
Bulk density (g/cm^3)	0.130	0.103	- 0.117
Sand (kg/kg)	- 0.181	- 0.18	- 0.001
Silt (kg/kg)	- 0.112	- 0.137	- 0.108
Clay (kg/kg)	0.194	0.221	0.112
Chemical			
pH	0.168	0.122	- 0.165
Electrical conductivity (dS/m)	- 0.098	- 0.108	0.032
Organic matter (g/kg)	0.093	0.049	- 0.122
Extractable P (kg/ha)	- 0.255	- 0.262	0.013
Extractable K (kg/ha)	- 0.058	- 0.080	- 0.081
Extractable Ca (kg/ha)	0.087	0.051	- 0.123
Extractable Mg (kg/ha)	0.088	0.017	- 0.274
Extractable Na (kg/ha)	0.018	0.010	0.010
Extractable S (kg/ha)	- 0.127	- 0.079	0.220
Extractable Fe (kg/ha)	- 0.009	- 0.056	- 0.180
Extractable Mn (kg/ha)	0.128	0.071	- 0.221
Extractable Cu (kg/ha)	- 0.125	- 0.080	- 0.173
Extractable Zn (kg/ha)	- 0.132	- 0.158	- 0.080
Extractable B (kg/ha)	- 0.167	- 0.206	- 0.126
Biological			
Bacterial biomass (g/m^2)	0.017	- 0.061	- 0.340*
Fungal biomass (g/m^2)	0.011	- 0.064	- 0.334*
Fungal-to-bacterial biomass ratio	- 0.039	- 0.149	- 0.483**

* Significant at $0.001 < P \leq 0.01$; **Significant at $P \leq 0.001$.

In addition to what was hypothesized, we expected similar trends in DM, yield, and HI between the soybean and rice crops. For example, we expected areas that had high soybean DM or seed yield to have high DM and seed yield for the rice crop. However, there was no correlation between soybean and rice DM or HI, but there was a marginal (P = 0.063) negative correlation (r = - 0.268) between rice and soybean seed yield. Though not anticipated, this result indicates that areas that produced low soybean yields tended to produce high rice yields. For both rice and soybean, yield and DM yield within each crop were highly and positively correlated with areas of high DM producing high yields with HI proportional to that of areas producing low DM and yield. This observation suggests that the soil fertility requirements for each of these crops were quite different. Factors such as surface drainage rather than the properties we measured may have contributed to the growth and yield differences for each or both of these crops.

Some of the results of this study can be explained by taking into account potential yield-limiting ranges for several soil chemical properties evaluated in this study. Within the soil pH range following land leveling (i.e., pH 6 to 8.1; Table 1), a yield response would not have necessarily been expected for soybean unless the pH caused a nutrient deficiency and/or the added fertilizers failed to supply adequate nutrients resulting in poor growth, but a rice yield response would have been expected with these soil pH conditions, especially when accompanied by low soil-test Zn, P, or both (17). In Arkansas, Zn fertilizer is not recommended for soybean, but is recommended for rice grown on silt-loam soils with pH > 6.0 and Mehlich-3 Zn < 7.8 kg/ha. Application of Zn fertilizer to rice would have prevented growth and yields reductions associated with Zn deficiency of rice. However, soybean seed yield (Table 2), but not rice seed yield (Table 3), was significantly positively correlated with soil pH. The soil pH range in the top 10 cm before and after land leveling was relatively high and was probably due to the relatively high concentration of dissolved Ca, Mg, and bicarbonates in the groundwater used for irrigation (18). In Arkansas, soil P tends to be yield-limiting at high pH for rice, but not soybean. In this study, the entire range of post-leveling soil P concentrations was below what is considered to be a yield limitation for soybean and rice in eastern Arkansas (19). Phosphorus was likely deficient for the first soybean crop. Phosphorus deficiency in rice following land leveling is also common in the Mississippi River delta region (10), but rice seed yield was not correlated with extractable P suggesting that the flooded-soil conditions likely improved the availability of P (17). Concentration ranges for soil extractable Ca and Mg were well above the concentrations considered to be yield-limiting in eastern Arkansas (19), therefore, with no deficiency, no yield response occurred and no correlation was detected (Table 3). In addition, the lack of correlation between post-leveling soil properties, particularly soil P and K concentrations, and second-year rice production may simply be due to enhanced nutrient availability often observed in a flooded soil environment as well as the application of P and K fertilizers (17). In contrast, depth of cut may have been the significant determining factor for subsequent crop productivity rather than any specific soil properties (10).

Zinc is typically the most limiting soil micro-nutrient for many crops grown in the Delta region of eastern Arkansas, and was significantly positively correlated with soybean above-ground DM yield, but significantly negatively correlated with soybean HI. Resulting micro-nutrient correlations with soybean DM and HI may be indirectly related to soil pH because the availability of most micronutrients decreases as pH increases. Optimum nutrient availability leads to high above-ground DM (i.e., positive correlations) and high DM tends to decrease HI (i.e., negative correlations; Table 2). However, the concentration ranges for Mn, Cu, and Zn following land leveling were all above that which would be considered deficient and yield-limiting for most agronomic crops.

Crop Production Predictability From Post-leveling Soil Properties

Despite numerous significant correlations among crop production parameters and post-leveling soil properties, multiple regression analyses resulted in no significant relationships among crop production parameters and post-leveling soil properties ($P > 0.15$ and $0.40 < r^2 < 0.55$ for whole model). When all measured soil properties were included in multiple regression analyses, no post-leveling soil variable was significant in the model ($P > 0.05$ for all individual variables) attempting to predict yield, above-ground DM, or HI separately for first-year soybean or second-year rice following shallow land leveling. Therefore, within the context of this small study area that has been thoroughly characterized, it must be concluded that first-year soybean and second-year rice production cannot be predicted from a relatively comprehensive assessment of post-land-leveling soil properties.

Practical Implications

Knowing which post-leveling soil properties positively, or negatively, relate to crop production parameters, especially yield, could facilitate improved crop management. For example, if soil nutrients other than those commonly used as fertilizers (i.e., N, P, and K) are known to correlate positively with yield in a newly land-leveled area, a producer can add those nutrients accordingly to gain more uniform crop growth, a better yield, and potentially a greater profit margin.

From this field study, it was determined that numerous post-leveling soil physical, chemical, and biological properties correlated with crop production parameters when soybean was grown as the first crop following shallow land leveling and fertilized according to University of Arkansas recommendations. Many soil chemical and biological properties had a positive correlation with above-ground DM in the first-year soybean crop, but a negative correlation with HI. When rice was grown as the second crop following land leveling, there were few positive correlations among crop production parameters and soil physical, chemical, and biological properties. This may be due to the recovery of soil fertility through fertilization after one growing season and/or the flooded-soil conditions. However, when all post-leveling soil property information was considered, no significant predictive relationship resulted among crop production parameters and post-leveling soil properties. Therefore, the results of this study indicate that a comprehensive assessment of post-leveling soil physical, chemical, and biological properties, including those soil properties that would be most obvious to a producer and easily obtainable through a routine soil analysis, was of little value to predict crop response following shallow land leveling activities.

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