



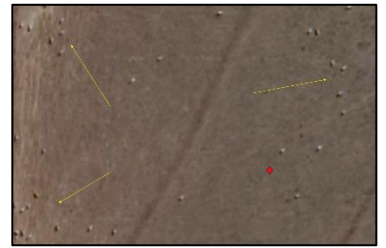
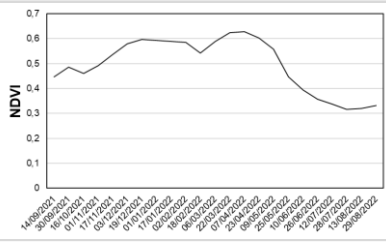
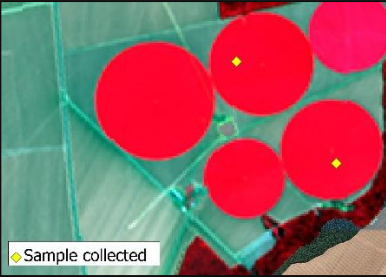
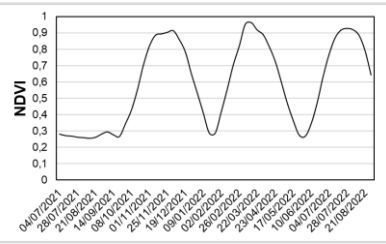
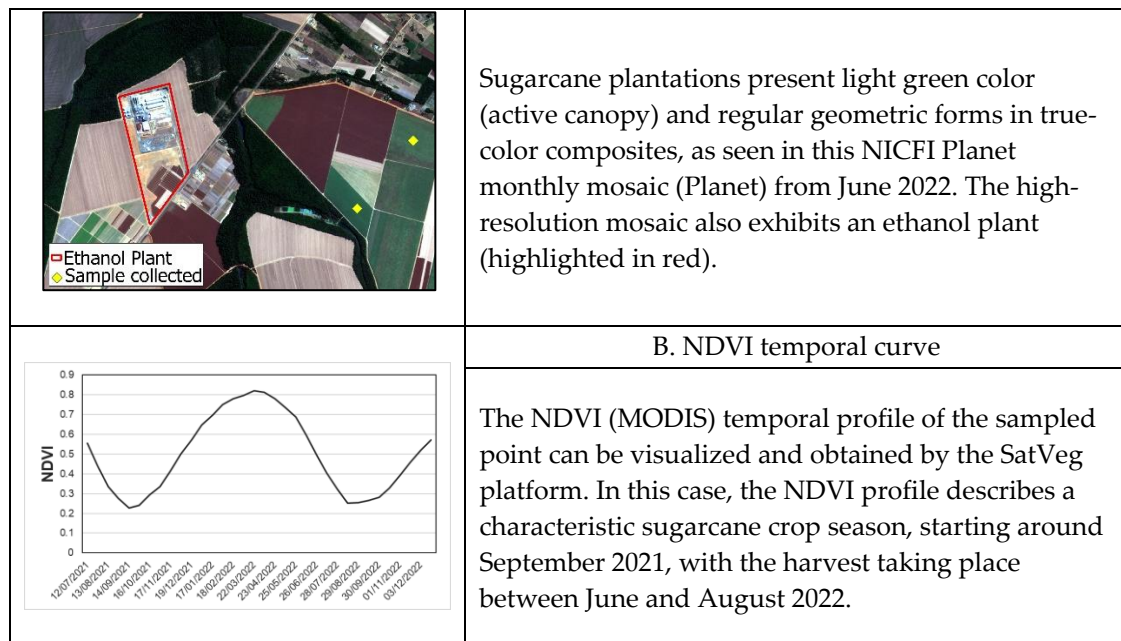


Supplementary material for “Mapping Agricultural Intensification in the Brazilian Savanna: A Machine Learning Approach using Harmonized Data from Landsat Sentinel-2” by Édson L. Bolfe (edson.bolfe@embrapa.br) and co-authors.

Figure S1. Examples of elements and interpretation keys used to collect accurate remote samples of natural vegetation, pasturelands, planted forests, triple cropping, and sugarcane, in Sorriso-MT, Brazil, in the 2021-2022 crop season.

Level 2 - Natural Vegetation	
	A. RGB Composite (NIR-R-G) – HLS 30 m – ‘2022-06-20’
	<p>Color: dark red to dark greenish, depending on the formation (forest Level 2 - or non-forest)</p> <p>Texture: rough (forest formations) to flat (non-forest)</p> <p>Context: The native vegetation of the Cerrado in Sorriso-MT follows the direction of water courses, forming preservation areas. Clearings may occur within forest formations where the vegetation becomes less dense.</p> <p>Coordinates: 55° 41’ 20.87” W, 12° 50’ 7.23” S (WGS84)</p>
Level 2 - Planted Forest (Silviculture)	
	A. RGB composite (NIR-R-G) – HLS 30 m – ‘2022-06-20’
	<p>Color: bright red</p> <p>Texture: flat</p> <p>Context: regular geometric patterns are associated with planting plots. When the wood is harvested, whitish clearings appear, influenced by the exposed soil and remaining wood.</p> <p>Coordinates: 55° 43’ 6.99” W, 12° 56’ 56.27” S (WGS84)</p>
	B. RGB true-color composite – NICFI Planet 4.77 m
	<p>The presence of planted forests can be confirmed using a high-resolution image, such as this NICFI Planet monthly mosaic from June 2022 (Imagery © 2022 Planet Labs Inc).</p>
Level 2 - Pasture	
	A. RGB composite (NIR-R-G) – HLS – ‘2022-06-20’
	<p>Color: light pink to greenish, depending on the state of the pasture.</p> <p>Texture: smooth to medium.</p> <p>Context: allocated between forest (on the right) and annual agriculture (on the left). There may be</p>

 <p>• Sample collected • Pasture</p>	<p>presence of termite mounds, exposed soil and/or regrowth of native vegetation. Coordinates: 55° 40' 44.25" W, 12° 51' 44.94" S (WGS84)</p>
	<p>B. High-resolution image - Google Satellite</p> <p>Additional evidence: presence of animals on the pasture (visible only from very high-resolution images).</p>
	<p>C. NDVI temporal curve</p> <p>The NDVI (MODIS) temporal profile of the sampled point can be visualized and obtained by the SatVeg platform. This profile becomes additional evidence. In this case, the NDVI profile is characteristic: it did not exceed 0.7 throughout the crop year (2021-2022), with an upward trend in the rainy season (from September to March) and a downward trend in the dry season (from April).</p>
<p>Level 3 – Triple Cropping</p>	
 <p>• Sample collected</p>	<p>A. RGB composite (NIR-R-G) – HLS – '2022-08-02'</p> <p>Color: bright red at the peak of the cycle Texture: smooth Context: regular geometric pattern. Intensification at triple cropping is made possible by irrigation, mainly carried out by center pivot systems in Cerrado. 541 Coordinates: 55° 18' 19.47" W, 13° 9' 5.51" S (WGS84)</p>
	<p>B. NDVI temporal curve</p> <p>The NDVI (MODIS) temporal profile of the sampled point can be visualized and obtained by the SatVeg platform. In this case, the NDVI profile shows the occurrence of three cropping seasons between September 2021 to August 2022.</p>
<p>Level 3 – Single Cropping (Sugarcane)</p>	
	<p>A. RGB true-color composite – NICFI Planet 4.77 m</p>



Where NICFI is Norwegian International Climate and Forest Initiative.

Table S1. Confusion matrices, omission, and commission (%) errors for Level 1 classifications using Random Forest (RF) algorithm and Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Soil-Adjusted Vegetation Index (SAVI) and the three indices combined (All VI).

Level 1 - RF – NDVI					Level 1 - RF - NDWI				
Classes	Temp. crop	Nat.Veg./Silv.	Pasture	O.E.	Classes	Temp. crop	Nat.Veg./Silv.	Pasture	O.E.
Temp. crop	39	2	4	13.33	Temp. crop	38	2	6	17.39
Nat.Veg./Silv.	0	47	0	0	Nat.Veg./Silv.	0	47	0	0
Pasture	2	0	54	3.57	Pasture	3	0	52	5.45
C.E.	4.88	4.08	6.90		C.E.	7.32	4.08	10.34	
Level 1 - RF – SAVI					Level 1 - RF – All VI				
Classes	Temp. crop	Nat.Veg./Silv.	Pasture	O.E.	Classes	Temp. crop	Nat.Veg./Silv.	Pasture	O.E.
Temp. crop	39	2	4	13.33	Temp. crop	41	3	4	14.58
Nat.Veg./Silv.	0	47	0	0	Nat.Veg./Silv.	0	46	1	2.13
Pasture	2	0	54	3.57	Pasture	0	0	53	0
C.E.	4.88	4.08	6.90		C.E.	0	6.12	8.62	

Where: Temp. crop is temporary crops; Nat.Veg./Silv. is natural vegetation and silviculture; O.E. is omission errors and C.E. is commission errors.

Table S2. Confusion matrices, omission and commission errors for Level 1 classifications using Artificial Neural Networks (ANN) algorithm and Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Soil-Adjusted Vegetation Index (SAVI) and the three indices combined (All VI).

Level 1 - ANN – NDVI					Level 1 - ANN - NDWI				
Classes	Temp. crop	Nat.Veg./Silv.	Pasture	O.E.	Classes	Temp. crop	Nat.Veg./Silv.	Pasture	O.E.
Temp. crop	36	1	2	7.69	Temp. crop	36	1	2	7.69
Nat.Veg./Silv.	0	48	1	2.04	Nat.Veg./Silv.	0	48	0	0.00
Pasture	5	0	55	8.33	Pasture	5	0	56	8.20
C.E.	12.20	2.04	5.17		C.E.	12.20	2.04	3.45	
Level 1 - ANN – SAVI					Level 1 - ANN – All VI				
Classes	Temp. crop	Nat.Veg./Silv.	Pasture	O.E.	Classes	Temp. crop	Nat.Veg./Silv.	Pasture	O.E.
Temp. crop	36	1	2	7.69	Temp. crop	43	2	2	8.51
Nat.Veg./Silv.	1	48	0	2.04	Nat.Veg./Silv.	1	47	0	2.08
Pasture	4	0	56	8.33	Pasture	5	0	47	9.62
C.E.	12.20	2.04	5.17		C.E.	12.24	4.08	4.08	

Where: Temp. crop is temporary crops; Nat.Veg./Silv. is natural vegetation and silviculture; O.E. is omission errors and C.E. is commission errors.

Table S3. Confusion matrices, omission and commission errors for Level 1 classifications using Extreme Gradient Boosting (XGBoost) algorithm and Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Soil-Adjusted Vegetation Index (SAVI) and the three indices combined (All VI).

Level 1 - XGboost – NDVI					Level 1 - XGboost - NDWI				
Classes	Temp. crop	Nat.Veg./Silv.	Pasture	O.E.	Classes	Temp. crop	Nat.Veg./Silv.	Pasture	O.E.
Temp. crop	38	1	4	11.63	Temp. crop	38	2	6	17.39
Nat.Veg./Silv	0	48	1	2.04	Nat.Veg./Silv	0	47	0	0
Pasture	3	0	53	5.36	Pasture	3	0	52	5.45
C.E.	7.32	2.04	8.62		C.E.	7.32	4.08	10.34	
Level 1 - XGboost – SAVI					Level 1 - XGboost – All VI				
Classes	Temp. crop	Nat.Veg./Silv.	Pasture	O.E.	Classes	Temp. crop	Nat.Veg./Silv.	Pasture	O.E.
Temp. crop	38	1	4	11.63	Temp. crop	43	2	2	8.51
Nat.Veg./Silv	0	48	1	2.04	Nat.Veg./Silv	1	47	0	2.08
Pasture	3	0	53	5.36	Pasture	5	0	47	9.62
C.E.	7.32	2.04	8.62		C.E.	12.24	4.08	4.08	

Where: Temp. crop is temporary crops; Nat.Veg./Silv. is natural vegetation and silviculture; O.E. is omission errors and C.E. is commission errors.

Table S4. Confusion matrices, omission and commission errors for Level 2 classifications using Random Forest (RF) algorithm and Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Soil-Adjusted Vegetation Index (SAVI) and the three indices combined (All VI).

Level 2 - RF – NDVI					Level 2 - RF - NDWI				
Classes	Double crop	Single crop	Triple crop	O.E.	Classes	Double crop	Single crop	Triple crop	O.E.
Double crop	55	3	0	5.17	Double crop	54	2	0	3.57
Single crop	0	24	0	0	Single crop	1	25	1	7.41
Triple crop	0	0	30	0	Triple crop	0	0	29	0
C.E.	0	11.11	0		C.E.	1.82	7.41	3.33	
Level 2 - RF – SAVI					Level 2 - ANN – AllVI				
Classes	Double crop	Single crop	Triple crop	O.E.	Classes	Double crop	Single crop	Triple crop	O.E.
Double crop	69	2	1	4.17	Double crop	54	3	0	5.26
Single crop	0	25	0	0	Single crop	0	24	0	0
Triple crop	0	0	28	0	Triple crop	1	0	30	3.23
C.E.	0	7.41	3.45		C.E.	1.82	11.11	0	

Where: O.E. is omission errors and C.E. is commission errors.

Table S5. Confusion matrices, omission and commission errors for Level 2 classifications using Artificial Neural Networks (ANN) algorithm and Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Soil-Adjusted Vegetation Index (SAVI) and the three indices combined (All VI).

Level 2 - ANN – NDVI					Level 2 – ANN - NDWI				
Classes	Double crop	Single crop	Triple crop	O.E.	Classes	Double crop	Single crop	Triple crop	O.E.
Double crop	61	5	0	7.58	Double crop	65	1	4	7.14
Single crop	2	23	1	11.54	Single crop	0	27	1	3.57
Triple crop	3	0	27	10.00	Triple crop	1	0	23	4.17
C.E.	7.58	17.86	3.57		C.E.	1.52	3.57	17.86	
Level 2 - ANN – SAVI					Level 2 - ANN – AllVI				
Classes	Double crop	Single crop	Triple crop	O.E.	Classes	Double crop	Single crop	Triple crop	O.E.
Double crop	61	1	0	1.61	Double crop	64	0	0	0
Single crop	4	27	0	12.90	Single crop	2	28	2	12.50
Triple crop	1	0	28	3.45	Triple crop	0	0	26	0
C.E.	7.58	3.57	0		C.E.	3.03	0	7.14	

Where: O.E. is omission errors and C.E. is commission errors.

Table S6. Confusion matrices, omission and commission errors for Level 2 classifications using Extreme Gradient Boosting (XGBoost) algorithm and Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Soil-Adjusted Vegetation Index (SAVI) and the three indices combined (All VI).

Level 2 - XGBoost – NDVI					Level 2 – XGBoost - NDWI				
Classes	Double crop	Single crop	Triple crop	O.E.	Classes	Double crop	Single crop	Triple crop	O.E.
Double crop	65	0	0	0	Double crop	66	1	3	5.71
Single crop	1	28	0	3.45	Single crop	0	27	0	0
Triple crop	0	0	28	0	Triple crop	0	0	25	0
C.E.	1.52	0	0		C.E.	0	3.57	10.71	
Level 2 - XGBoost – SAVI					Level 2 – XGBoost - All VI				
Classes	Double crop	Single crop	Triple crop	O.E.	Classes	Double crop	Single crop	Triple crop	O.E.
Double crop	62	0	2	3.13	Double crop	65	0	4	5.80
Single crop	0	28	0	0	Single crop	1	28	0	3.45
Triple crop	4	0	26	13.33	Triple crop	0	0	24	0

C.E.	6.06	0	7.14	C.E.	1.52	0	14.29
------	------	---	------	------	------	---	-------

Where: O.E. is omission errors and C.E. is commission errors.

Table S7. Confusion matrices, omission and commission errors for Level 3 classifications using Random Forest (RF) algorithm and Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Soil-Adjusted Vegetation Index (SAVI) and the three indices combined (All VI).

Level 3 - RF – NDVI						Level 3 - RF - NDWI					
Classes	Beans	Corn	Cotton	Other*	O.E.	Classes	Beans	Corn	Cotton	Other*	O.E.
Beans	23	0	0	0	0	Beans	24	0	0	0	0
Corn	0	52	1	1	3.70	Corn	0	53	2	5	11.67
Cotton	0	0	29	0	0	Cotton	0	0	29	1	3.33
Other*	0	3	1	30	11.76	Other*	0	2	0	24	7.69
C.E.	0	5.45	6.45	3.23		C.E.	0	3.54	6.45	20.00	
Level 3 - RF – SAVI						Level 3 - RF – AllVI					
Classes	Beans	Corn	Cotton	Other*	O.E.	Classes	Beans	Corn	Cotton	Other*	O.E.
Beans	24	0	0	0	0	Beans	23	0	0	1	4.17
Corn	0	50	1	2	5.66	Corn	0	52	1	2	5.45
Cotton	0	0	29	0	0	Cotton	0	0	29	0	0
Other*	0	5	1	29	17.14	Other*	0	3	1	28	12.50
C.E.	0	9.09	6.45	6.45		C.E.	0	5.45	6.45	9.68	

Where: * other crops planted in the second season; O.E. is omission errors and C.E. is commission errors.

Table S8. Confusion matrices, omission and commission errors for Level 3 classifications using Artificial Neural Networks (ANN) algorithm and Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Soil-Adjusted Vegetation Index (SAVI) and the three indices combined (All VI).

Level 3 - ANN – NDVI						Level 3 - ANN - NDWI					
Classes	Beans	Corn	Cotton	Other*	O.E.	Classes	Beans	Corn	Cotton	Other*	O.E.
Beans	27	3	0	0	10.00	Beans	28	2	0	0	6.67
Corn	0	60	0	4	6.25	Corn	0	59	1	1	3.28
Cotton	0	0	27	0	0	Cotton	0	0	26	0	0
Other*	0	3	0	23	11.54	Other*	0	5	0	26	16.13
C.E.	0	9.09	0	14.81		C.E.	0	10.61	3.70	3.70	

Level 3 - ANN – SAVI						Level 3 – ANN - AllVI					
Classes	Beans	Corn	Cotton	Other*	O.E.	Classes	Beans	Corn	Cotton	Other*	O.E.
Beans	28	0	3	3	9.68	Beans	26	0	0	0	0
Corn	0	62	1	1	3.13	Corn	0	64	1	2	4.48
Cotton	0	0	24	0	0	Cotton	1	1	26	0	7.14
Other*	0	4	2	23	20.69	Other*	0	1	0	25	3.85
C.E.	0	6.06	11.11	14.81		C.E.	3.70	3.03	3.70	7.41	

Where: * other crops planted in the second season; O.E. is omission errors and C.E. is commission errors.

Table S9. Confusion matrices, omission and commission errors for Level 3 classifications using Extreme Gradient Boosting (XGBoost) algorithm and Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Soil-Adjusted Vegetation Index (SAVI) and the three indices combined (All VI).

Level 3 - XGBoost – NDVI						Level 3 - XGBoost - NDWI					
Classes	Beans	Corn	Cotton	Other*	O.E.	Classes	Beans	Corn	Cotton	Other*	O.E.
Beans	27	0	0	0	0	Beans	26	1	0	0	3.70
Corn	0	64	0	2	3.03	Corn	0	63	3	0	4.55
Cotton	0	1	27	0	3.57	Cotton	2	0	22	0	8.33
Other*	0	1	0	25	3.85	Other*	0	2	2	27	12.90
C.E.	0	3.03	0	7.41		C.E.	7.14	4.55	18.52	0	

Level 3 - XGBoost – SAVI						Level 3 - XGBoost – SAVI					
Classes	Beans	Corn	Cotton	Other*	O.E.	Classes	Beans	Corn	Cotton	Other*	O.E.
Beans	26	1	0	0	3.70	Beans	26	0	0	0	0
Corn	2	62	1	1	6.06	Corn	0	64	1	2	4.48
Cotton	0	1	24	0	4.00	Cotton	1	1	26	0	7.14
Other*	0	2	2	26	13.33	Other*	0	1	0	25	3.85
C.E.	7.14	6.06	11.11	3.70		C.E.	3.70	3.03	3.70	7.41	

Where: * other crops planted in the second season; O.E. is omission errors and C.E. is commission errors.

Table S10. Results of analysis of variance (ANOVA) considering the performance of classification algorithms (Random Forest, Artificial Neural Networks, and Extreme Gradient Boosting) at classification levels 1, 2, 3. Results with Pr (>F) lower than 0.05 indicate statistical difference between the performance of models with a 95% confidence interval.

Level	Metric	Df.	Sum. Sq.	Mean Sq.	F value	Pr (>F)
Level 1	Kappa	2	0.0003626	0.0001813	1.096	0.375
	Accuracy	2	0.0001615	8.076e-05	1.087	0.378
Level 2	Kappa	2	0.005065	0.0025324	2.959	0.103
	Accuracy	2	0.001783	0.0008913	2.869	0.109
Level 3	Kappa	2	0.000407	0.0002034	0.396	0.684
	Accuracy	2	0.0002297	0.0001148	0.45	0.651