

# Questions We Try To Answer In These Slides for all 3 satellites- Landsat-7, Landsat-8, and Sentinel-2

Ques 1) Does BU/NBU accuracy improve when we use 2015 and 2020 images to improve the corner years under analysis i.e. 2016 and 2019?

Ques 2) What is the performance of the Change Classification (Without Regression-based Method) for both improved corner years and un-improved corner years?

Ques 3) What threshold should be used for the “Fixed threshold-based regression change detection”? Should this threshold be common across cities and satellites?

**Answers in the last slide**

# **Testing BU/NBU Accuracy of Landcover Predictions for all 4 years**

**-Chahat Bansal and Hariom Ahlawat**

# New BU/NBU Groundtruth Details

1. The CBU/CNBU groundtruth for 6 cities is chosen for this testing as they for the BU/NBU groundtruth for all four years 2016-2019.
2. We intend to test the accuracy across 3 satellites- Landsat-7, Landsat-8, and Sentinel-2.
3. We also will test how much the accuracy changes when we improve the corner years 2016 and 2019 using the years 2015 and 2020.
4. **As of now we only compare Sentinel-2 (without corner year improvement) with Landsat-8 (with corner year improvement)**

City	#BU Pixels	#NBU Pixels
Bangalore	222	188
Chennai	156	175
Delhi	403	736
Gurgaon	449	568
Hyderabad	189	317
Mumbai	328	498
<b>Overall</b>	<b>1747</b>	<b>2482</b>

# **Testing BU/NBU Accuracy of Satellite WITH & WITHOUT Corner year Improvement**

- Corner years 2016 and 2019 are improved by keeping 2015 and 2020 in the pipeline of temporal smoothing**

	Landsat-7 (Without corner year improvement)				Landsat-7 (With corner year improvement)			
	2016	2017	2018	2019	2016	2017	2018	2019
	F1-score	F1-score	F1-score	F1-score	F1-score	F1-score	F1-score	F1-score
Bangalore	0.8366	0.8683	0.8927	0.8390	0.8659	0.8756	0.8878	0.8756
Chennai	0.7402	0.7613	0.7613	0.7039	0.7946	0.7976	0.8006	0.7946
Delhi	0.9140	0.9306	0.9298	0.9096	0.9482	0.9508	0.9508	0.9368
Gurgaon	0.9184	0.9420	0.9479	0.9272	0.9243	0.9322	0.9361	0.9302
Hyderabad	0.8874	0.9111	0.9111	0.7727	0.8913	0.9051	0.9051	0.8063
Mumbai	0.8898	0.9298	0.9370	0.9286	0.9237	0.9310	0.9346	0.9383
Overall	0.8860	0.9116	0.9165	0.8782	0.9109	0.9177	0.9208	0.9028

1. Corner year improvement gives better performance for Landsat-7.
2. The performance of Chennai is low followed by Bangalore for Landsat-7.

	Landsat-8 (Without corner year improvement)				Landsat-8 (With corner year improvement)			
	2016	2017	2018	2019	2016	2017	2018	2019
	F1-score	F1-score	F1-score	F1-score	F1-score	F1-score	F1-score	F1-score
Bangalore	0.8854	0.9073	0.9185	0.9171	0.8976	0.9146	0.9187	0.9220
Chennai	0.7976	0.7795	0.7492	0.6616	0.8127	0.8006	0.7825	0.7492
Delhi	0.9254	0.9271	0.9192	0.9017	0.9350	0.9368	0.9298	0.9148
Gurgaon	0.9390	0.9518	0.9518	0.9518	0.9469	0.9548	0.9548	0.9548
Hyderabad	0.9229	0.9407	0.9348	0.8933	0.9209	0.9368	0.9348	0.9130
Mumbai	0.9370	0.9153	0.9116	0.8644	0.9189	0.9128	0.9092	0.8814
Overall	0.9168	0.9189	0.9141	0.8882	0.9198	0.9236	0.9198	0.9054

1. Corner year improvement gives better performance for Landsat-8.
2. The performance of Chennai is low for Landsat-8 also.

	Sentinel-2 (Without corner year improvement)				Sentinel-2 (With corner year improvement)			
	2016	2017	2018	2019	2016	2017	2018	2019
	F1-score	F1-score	F1-score	F1-score	F1-score	F1-score	F1-score	F1-score
Bangalore	0.9049	0.9195	0.9220	0.9244	0.9024	0.9171	0.9195	0.9195
Chennai	0.9637	0.9698	0.9698	0.9698	0.9698	0.9789	0.9789	0.9789
Delhi	0.9728	0.9754	0.9745	0.9631	0.9719	0.9754	0.9754	0.9693
Gurgaon	0.9263	0.9410	0.9430	0.9410	0.9243	0.9390	0.9410	0.9400
Hyderabad	0.9427	0.9664	0.9684	0.9328	0.9466	0.9684	0.9723	0.9644
Mumbai	0.9516	0.9443	0.9346	0.9298	0.9540	0.9479	0.9407	0.9383
Overall	0.9466	0.9541	0.9529	0.9444	0.9470	0.9551	0.9548	0.9515

1. Corner year improvement gives overall better performance for Sentinel-2.
2. For Chennai and Kolkata 2015 images were not available.
3. The performance of Chennai is very good for Sentinel-2 than its Landsat counterparts.

# KEY TAKEAWAYS

1. Corner year improvements give better Landcover predictions and hence the regression based classifiers should be tested on them.
2. Chennai gives low results for Landsat-7 and Landsat-8.
3. Bangalore for Landsat-7 gives results ~85% accuracy. These can also be improved.



**Testing BU/NBU Accuracy of Satellites for the  
year 2018 over bigger groundtruth created by  
Hariom Sir**

# Groundtruth Details (Created for year 2018)

1. In these slides we test the BU/NBU accuracy of Landsat7, Landsat8, and Sentinel2.
2. For Landsat-7 and Landsat-8 we compare the performance of maps for which corner years 2016 and 2019 are temporally improved using 2015 and 2020 respectively. This is compared with maps where these corner years are not improved.

City	#BU Pixels	#NBU Pixels
Delhi	423	676
Gurgaon	2457	2365
Hyderabad	2209	1350
Mumbai	2398	1498

Accuracy Test For Year 2018	Landsat-7 (Without Corner Year Improvement)		Landsat-7 (With Corner Year Improvement)		Landsat-8 (Without Corner Year Improvement)		Landsat-8 (With Corner Year Improvement)		Sentinel-2 (Without Corner Year Improvement)		Sentinel-2 (With Corner Year Improvement)	
	F1	Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc
Delhi	0.92	92.08%	0.94	93.99%	0.90	89.71%	0.90	89.89%	0.94	94.26%	0.95	94.54%
Gurgaon	0.98	98.29%	0.97	97.36%	0.99	98.65%	0.99	98.67%	0.99	98.58%	0.99	98.58%
Hyderabad	0.99	99.10%	0.99	98.65%	0.98	98.28%	0.98	98.34%	1.00	99.55%	1.00	99.57%
Mumbai	0.97	97.38%	0.94	94.48%	0.97	96.91%	0.97	97.02%	0.99	98.99%	0.99	98.94%

1. Sentinel-2 gives the best accuracy for all cities
2. Corner year improvement works only slightly better for Landsat-8 but not better for Landsat-7. This is okay because corner year improvement has higher impact on corner years and not intermediate years like **2018**

# **Change Classifier Accuracy Test**

**-Chahat Bansal, Deepanshu Singh & Hariom Ahlawat**

# New Groundtruth Details

(Created for 6 cities- Bangalore, Delhi, Chennai, Gurgaon, Hyderabad, and Mumbai)

**Total: 5300 Pixels**

**CBU: 1555**

**CNBU: 2417**

**Changing: 1328**

# Key points about new groundtruth

1. All points have been marked across the entire city. Help has been taken from Landsat8 images whose corner years (2016 and 2019) have been temporally improved using years 2015 and 2020 respectively.
2. Different polygons have been marked to capture spatial variability. Eg. CNBU has been taken from agricultural lands, parks, lakes, river, riverbanks..etc.
3. It is important to note that the polygons should be of atleast 450 m<sup>2</sup> to be evaluated as a pixel of resolution 30x30.

City	Pixel Type	#Polygons	#Pixels before balancing	#Pixels after groundtruth balancing
Bangalore	CBU	61	222	178
	CNBU	32	237	188
	Changing	84	200	200
Chennai	CBU	32	156	133
	CNBU	40	182	175
	Changing	68	111	111
Delhi	CBU	417	403	337
	CNBU	281	899	736
	Changing	256	364	364

City	Pixel Type	#Polygons	#Pixels before balancing	#Pixels after groundtruth balancing
Gurgaon	CBU	221	449	419
	CNBU	104	604	503
	Changing	123	414	414
Hyderabad	CBU	105	189	184
	CNBU	206	360	317
	Changing	148	101	101
Mumbai	CBU	108	328	304
	CNBU	123	503	498
	Changing	85	138	138



# Testing Change Detection **Without** Using Regression-based Change Classifier

Change Detection Overall Accuracy	Landsat-7 (Without Corner Year Improvement)		Landsat-7 (With Corner Year Improvement)		Landsat-8 (Without Corner Year Improvement)		Landsat-8 (With Corner Year Improvement)		Sentinel-2 (Without Corner Year Improvement)		Sentinel-2 (With Corner Year Improvement)	
	F1	Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc
Bangalore	0.6720	67.1%	0.6743	67.4%	0.7237	72.3%	0.7023	70.2%	0.7633	76.3%	0.7350	73.4%
Chennai	0.5274	52.7%	0.6014	60.1%	0.5537	55.3%	0.5919	59.1%	0.9165	91.6%	0.9236	92.3%
Delhi	0.8386	83.8%	0.8455	84.5%	0.8671	86.7%	0.8754	87.5%	0.9102	91.0%	0.8984	89.8%
Gurgaon	0.8600	86.0%	0.8690	86.9%	0.9154	91.5%	0.9179	91.7%	0.9034	90.3%	0.9027	90.2%
Hyderabad	0.7181	71.8%	0.7479	74.7%	0.8308	83.0%	0.8358	83.5%	0.8988	89.8%	0.9221	92.2%
Mumbai	0.8436	84.3%	0.8628	86.2%	0.8245	82.4%	0.8191	81.9%	0.8872	88.7%	0.8894	88.9%
Overall	0.7888	78.8%	0.8058	80.5%	0.8276	82.7%	0.8308	83.0%	0.8879	88.7%	0.8851	88.5%

1. Sentinel-2 gives the best change accuracy for all cities.
2. Bangalore performs the worst in terms of change detection accuracy for all satellites.
3. Chennai's change detection has acceptable results for Sentinel-2 but not for Landsat-7 or Landsat-8. This is possibly because the BU/NBU accuracy of Chennai for Landsats was also low.
4. Corner year improvement gives better change detection for Landsat satellites and comparable results for Sentinel-2

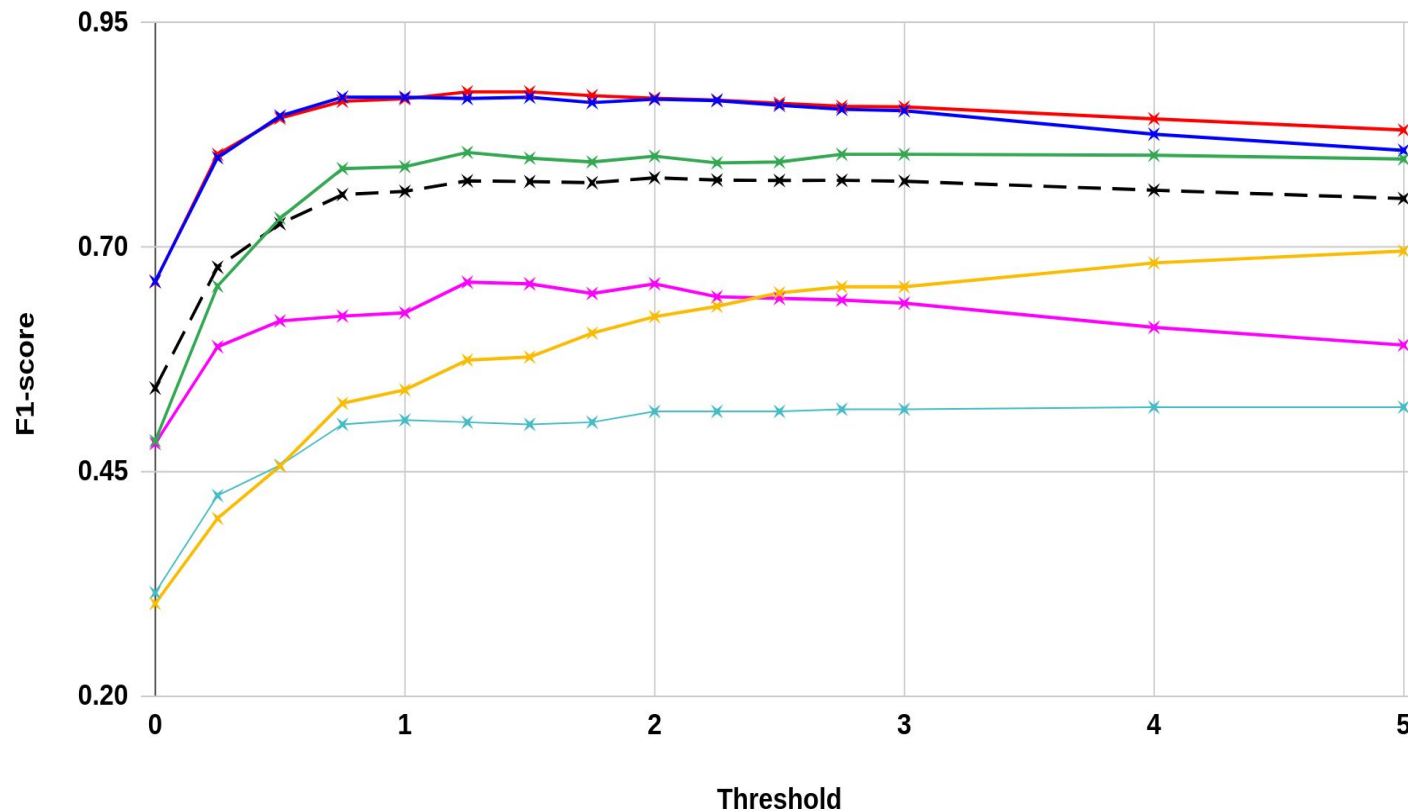
# KEY TAKEAWAYS

1. It is weird that despite having a good BU/NBU accuracy, Bangalore has a very low Change detection accuracy for all the satellites.
2. Chennai has a low change detection accuracy for Landsats which is consistent with its low BU/NBU accuracy for these satellites.

# **Experimenting with the thresholds of change classifier using Linear Regression**

## Testing Change Classifier Threshold for Landsat-7 (Without Corner Improvement)

× Overall\_F1 × Bangalore\_F1 × Chennai\_F1 × Delhi\_F1 × Gurgaon\_F1 × Hyderabad\_F1 × Mumbai\_F1



### Best Thresholds

Overall: **2.0**

Bangalore: **2.0**

Chennai: **4**

Delhi: **1.5**

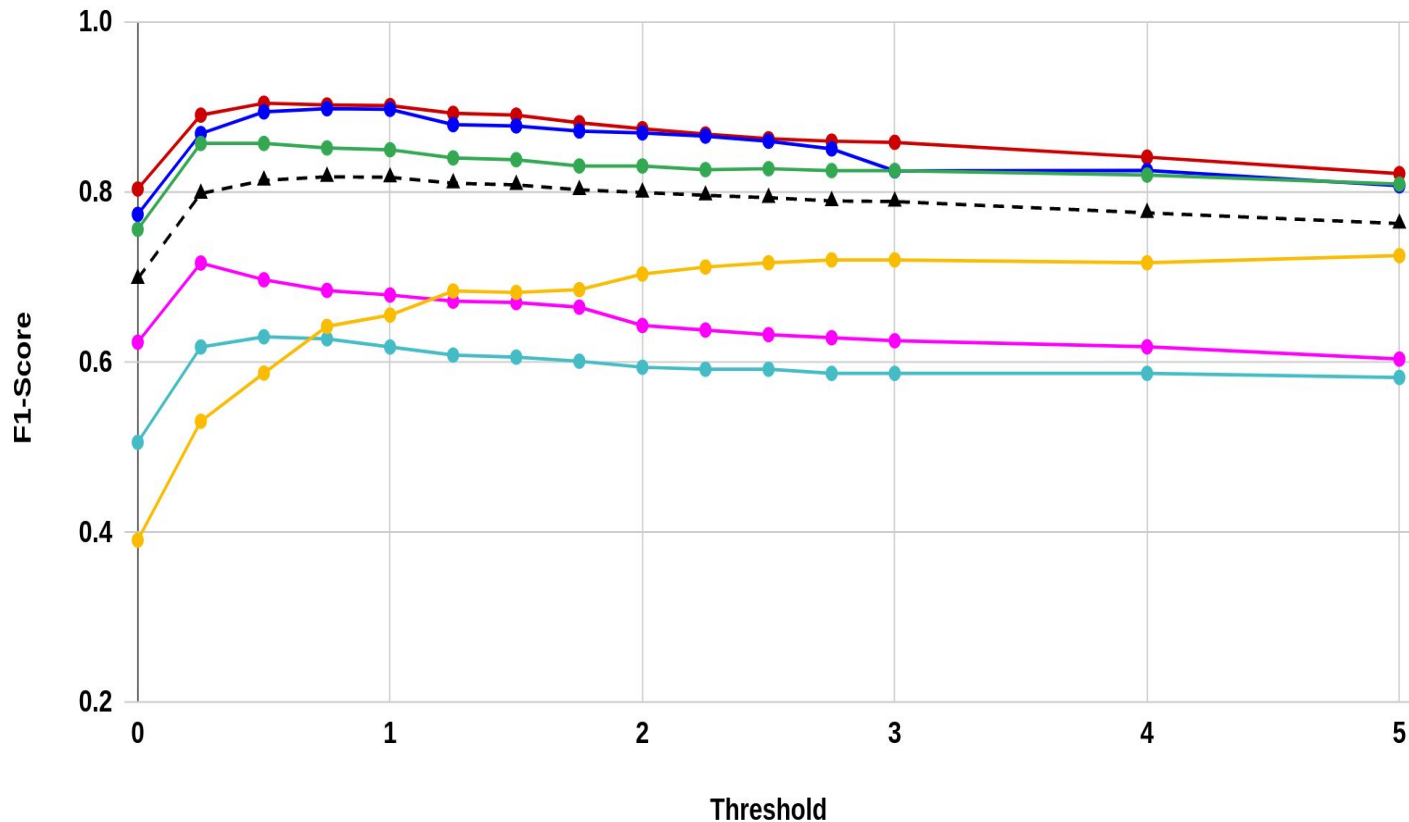
Gurgaon: **1.5**

Hyderabad: **5**

Mumbai: **2.75**

# Threshold Test for Landsat-7 (With Corner Year Improvement)

▲ Overall    ● Bangalore    ● Chennai    ● Delhi    ● Gurgaon    ● Hyderabad    ● Mumbai



## Best Thresholds

Overall: **0.75**

Bangalore: **0.25**

Chennai: **0.5**

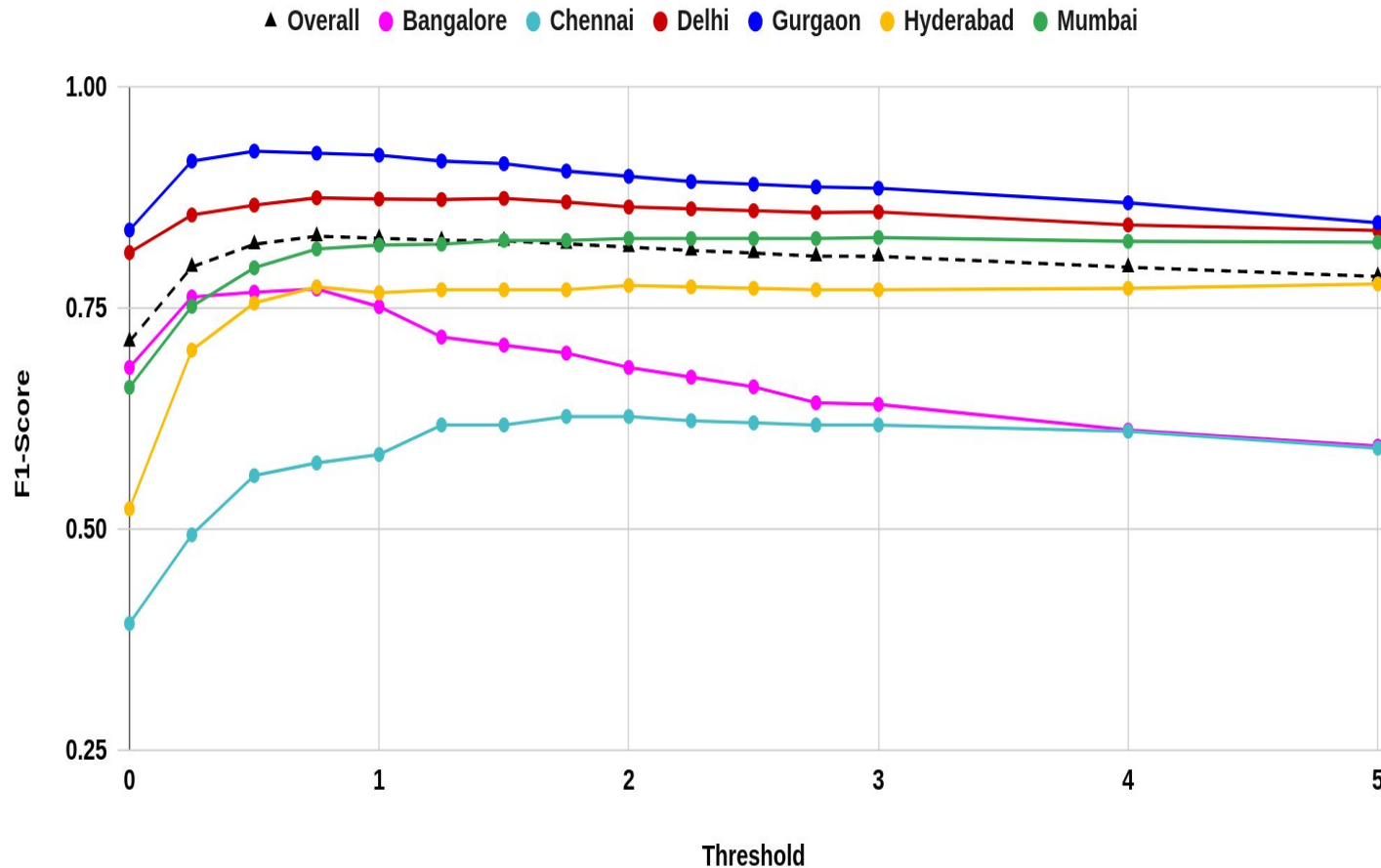
Delhi: **0.5**

Gurgaon: **0.75**

Hyderabad: **5**

Mumbai: **0.25**

# Threshold Test for Lansat-8 (Without Corner Year Improvement)



## Best Thresholds

Overall: **0.75**

Bangalore: **0.75**

Chennai: **1.75**

Delhi: **0.75**

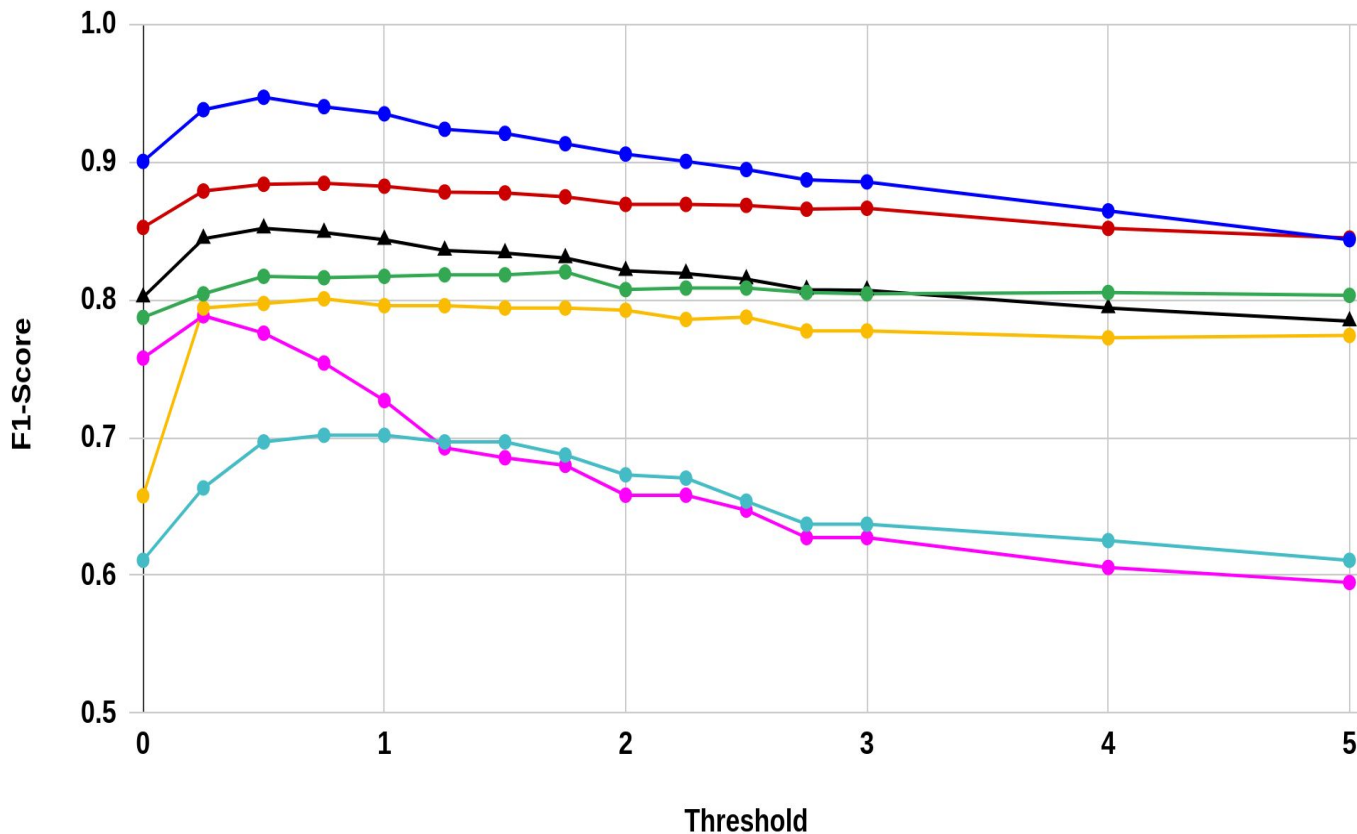
Gurgaon: **0.5**

Hyderabad: **5**

Mumbai: **3**

## Threshold Test for Landsat-8 (With Corner Year Improvement)

▲ Overall    ● Bangalore    ● Chennai    ● Delhi    ● Gurgaon    ● Hyderabad    ● Mumbai



### Best Thresholds

Overall: **0.5**

Bangalore: **0.25**

Chennai: **1.0**

Delhi: **0.75**

Gurgaon: **0.5**

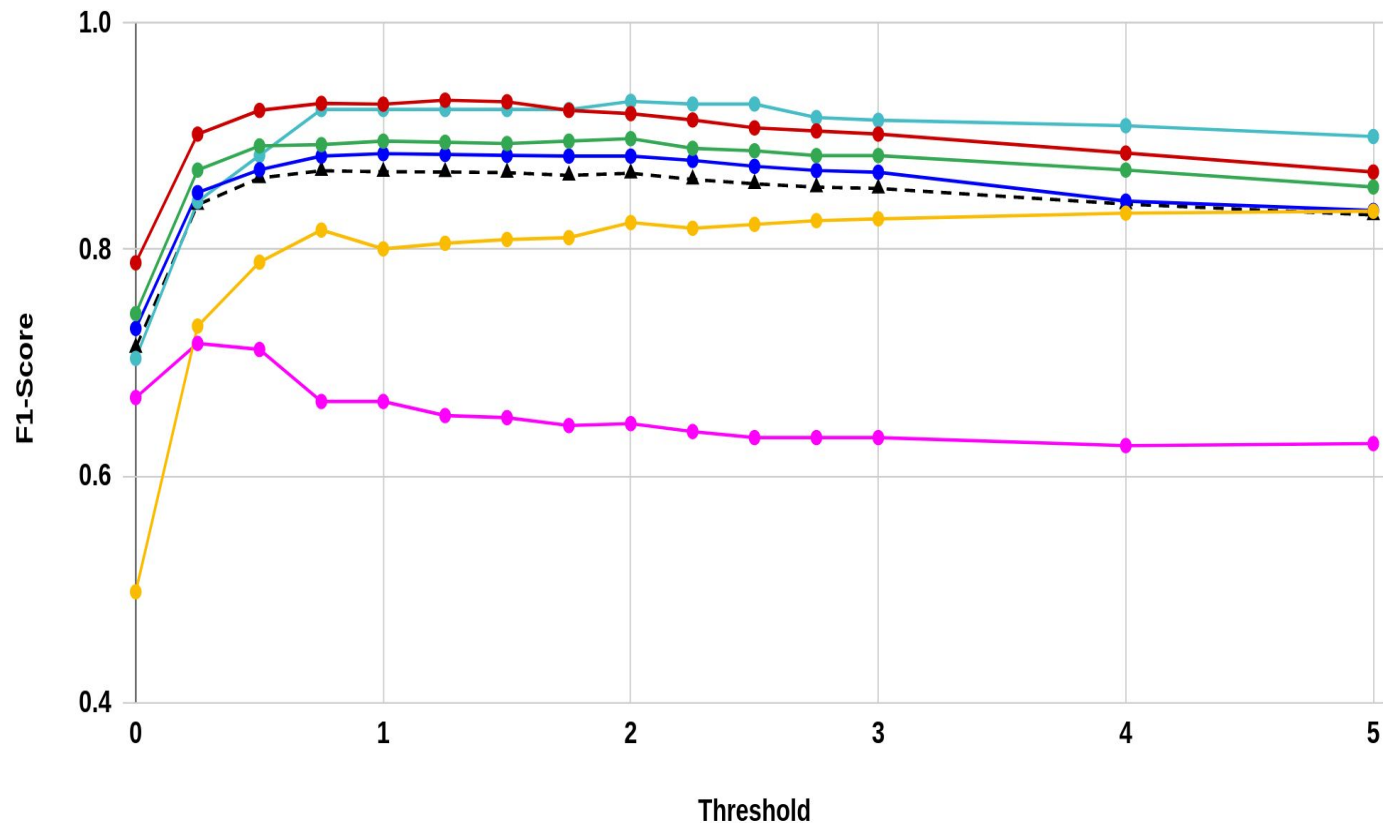
Hyderabad: **0.75**

Mumbai: **1.75**



# Threshold Test for Sentinel-2 Without Corner Year Improvement

▲ Overall    ● Bangalore    ● Chennai    ● Delhi    ● Gurgaon    ● Hyderabad    ● Mumbai



## Best Thresholds

Overall: **0.75**

Bangalore: **0.25**

Chennai: **2.0**

Delhi: **1.25**

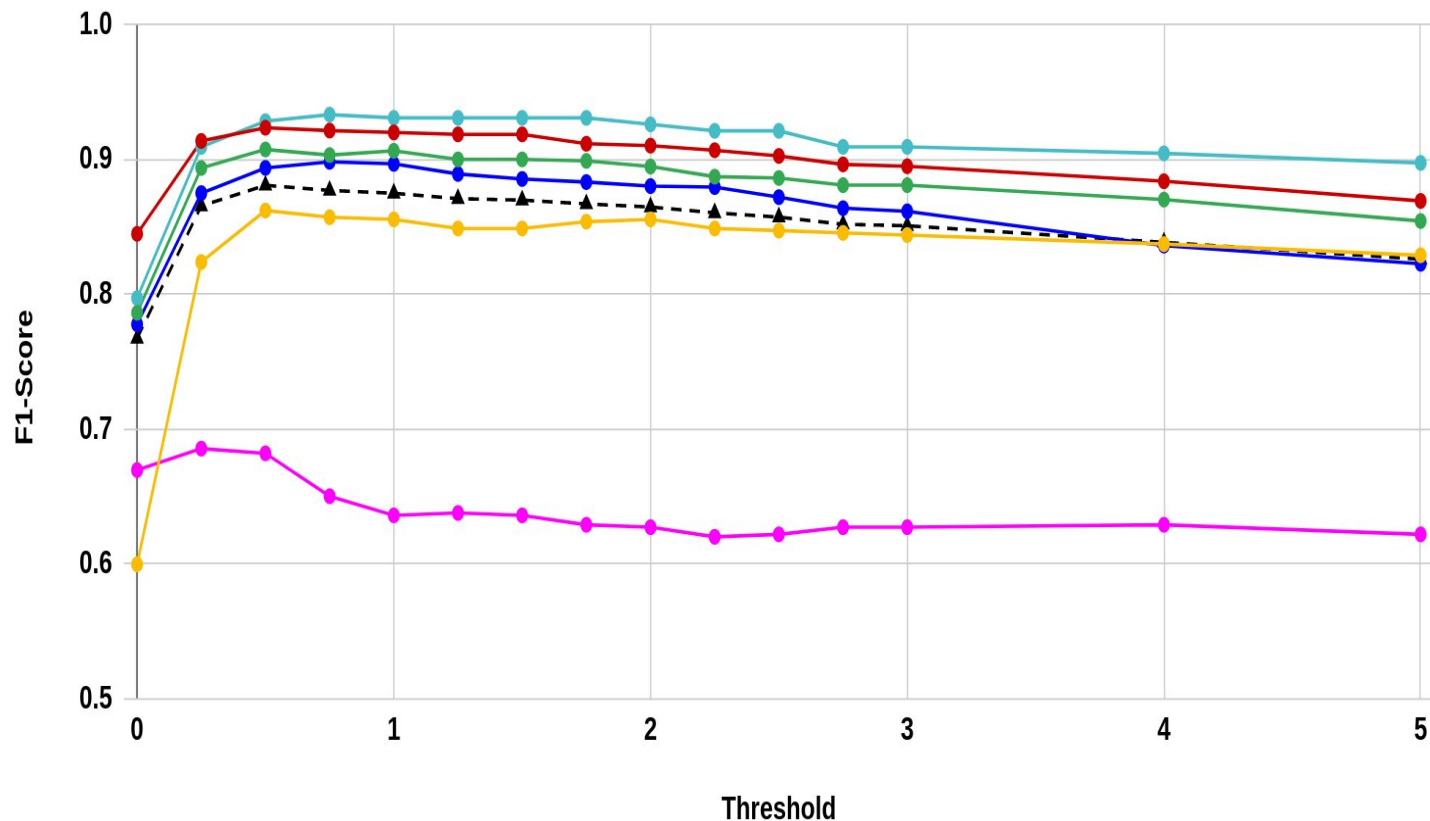
Gurgaon: **1.0**

Hyderabad: **5**

Mumbai: **2**

# Threshold Test for Sentinel-2 With Corner Year Improvement

▲ Overall    ● Bangalore    ● Chennai    ● Delhi    ● Gurgaon    ● Hyderabad    ● Mumbai



## Best Thresholds

Overall: **0.5**

Bangalore: **0.5**

Chennai: **1.0**

Delhi: **0.5**

Gurgaon: **0.75**

Hyderabad: **0.5**

Mumbai: **0.5**

Comparing Change Detection With and Without Linear Regression	Landsat-7 (Without Corner Year Improvement)		Landsat-7 (With Corner Year Improvement)		Landsat-8 (Without Corner Year Improvement)		Landsat-8 (With Corner Year Improvement)		Sentinel-2 (Without Corner Year Improvement)		Sentinel-2 (With Corner Year Improvement)	
	Without Regress	With Regress	Without Regress	With Regress	Without Regress	With Regress	Without Regress	With Regress	Without Regress	With Regress	Without Regress	With Regress
Bangalore	0.6720	0.6589	0.6743	0.7168	0.7237	0.7717	0.7023	0.7884	0.7633	0.7173	0.7350	0.682
Chennai	0.5274	0.5216	0.6014	0.6301	0.5537	0.6277	0.5919	0.7017	0.9165	0.9308	0.9236	0.9308
Delhi	0.8386	0.8727	0.8455	0.9047	0.8671	0.8747	0.8754	0.8845	0.9102	0.9318	0.8984	0.9235
Gurgaon	0.8600	0.8668	0.8690	0.8982	0.9154	0.9274	0.9179	0.9469	0.9034	0.8847	0.9027	0.8982
Hyderabad	0.7181	0.6955	0.7479	0.7255	0.8308	0.7774	0.8358	0.8007	0.8988	0.8339	0.9221	0.8621
Mumbai	0.8436	0.6564	0.8628	0.8574	0.8245	0.8298	0.8191	0.8202	0.8872	0.8979	0.8894	0.9074
Overall	0.7888	0.777	0.8058	0.8182	0.8276	0.8313	0.8308	0.8519	0.8879	0.8696	0.8851	0.8808

1. Regression-based change classifier improves accuracy for Chennai in Landsat-8
2. Regression-based change classifier is not working well for Hyderabad for any of the satellites.
3. For **Landsat-8 regression-based classifier generates better results especially for Chennai and Bangalore.**

# Questions We Try To Answer In These Slides for all 3 satellites- Landsat-7, Landsat-8, and Sentinel-2

**Ques 1) Does BU/NBU accuracy improve when we use 2015 and 2020 images to improve the corner years under analysis i.e. 2016 and 2019?**

**Ans)** Yes, the BU/NBU accuracy for all satellites improve when we use 2015 and 2020 images to temporally improve corner years.

**Ques 2) What is the performance of the Change Classification (Without Regression-based Method) for both improved corner years and un-improved corner years?**

**Ans)** Change classification without regression-based method gives clear improvement for improved corner years. This is intuitive because of the better BU/NBU accuracy. This improvement is higher in Landsat-7 and Landsat-8. For Sentinel-2 these results are comparable.

**Ques 3) What threshold should be used for the “Fixed threshold-based regression change detection”? Should this threshold be common across cities and satellites?**

**Ans)** The fixed threshold method requires different threshold values city-wise and satellite-wise. There isn't any one fixed threshold which works throughout. Also, the range of threshold values within a satellite is also diverse, like (5 for Hyderabad and 0.25 for Bangalore).

The fixed threshold value improved the change detection for Landsat-8 but was comparable for Sentinel-2.