



## Table of Contents

| <b>Introduction</b> |  |           |
|---------------------|--|-----------|
| <b>1.0.</b>         | <b><i>Forest Resources</i></b>   | <b>1</b>  |
| <b>1.1.</b>         | <b><i>Present vital problems and emerging issues</i></b>                     | <b>1</b>  |
| <b>1.2.</b>         | <b><i>Measuring a forest</i></b>   | <b>4</b>  |
| <b>1.3.</b>         | <b><i>Forest Inventory</i></b>   | <b>4</b>  |
| <b>1.4</b>          | <b><i>History of forest</i></b>  | <b>5</b>  |
| <b>1.5</b>          | <b><i>Conventional /Ground Survey method</i></b>                             | <b>7</b>  |
| <b>1.5.1.</b>       | <b><i>Primary Analysis</i></b>   | <b>7</b>  |
| <b>1.5.1.1.</b>     | <b><i>Species Composition</i></b>  | <b>7</b>  |
| <b>1.5.1.2.</b>     | <b><i>Phenology</i></b>  | <b>7</b>  |
| <b>1.5.1.3.</b>     | <b><i>Tree damage</i></b>  | <b>8</b>  |
| <b>1.5.2.</b>       | <b><i>Tree structure</i></b>   | <b>8</b>  |
| <b>1.5.2.1.</b>     | <b><i>DBH</i></b>  | <b>8</b>  |
| <b>1.5.2.2.</b>     | <b><i>Crown Cover</i></b>  | <b>8</b>  |
| <b>1.5.2.3.</b>     | <b><i>Height</i></b>   | <b>9</b>  |
| <b>1.5.2.4.</b>     | <b><i>Basal Area</i></b>   | <b>9</b>  |
| <b>1.5.3.</b>       | <b><i>Secondary analysis</i></b>   | <b>9</b>  |
| <b>1.5.3.1.</b>     | <b><i>Shannon-Wiener Diversity index</i></b>                                 | <b>9</b>  |
| <b>1.5.3.2.</b>     | <b><i>Margalef Index</i></b>   | <b>10</b> |
| <b>1.5.3.3.</b>     | <b><i>McIntosh Index</i></b>   | <b>10</b> |
| <b>1.5.3.4.</b>     | <b><i>Brillouin index</i></b>  | <b>10</b> |
| <b>1.6.</b>         | <b><i>Non-Conventional /RS-GIS Method of forest Inventory</i></b>            | <b>10</b> |
| <b>1.6.1.</b>       | <b><i>Remote sensing in forest Inventory</i></b>                             | <b>10</b> |
| <b>1.6.2.</b>       | <b><i>GIS in Forest Inventory</i></b>  | <b>12</b> |
| <b>2.0.</b>         | <b><i>Estimation of Biochemical and Biophysical parameters of Forest</i></b> | <b>13</b> |
| <b>3.0.</b>         | <b><i>Forest cover</i></b>   | <b>14</b> |
| <b>3.1.</b>         | <b><i>Optical remote sensing in forest mapping</i></b>                       | <b>15</b> |
| <b>3.2.</b>         | <b><i>Microwave Remote Sensing in forest mapping</i></b>                     | <b>15</b> |
| <b>3.2.1.</b>       | <b><i>Polarimetric decomposition</i></b>                                     | <b>16</b> |
| <b>4.0.</b>         | <b><i>Fusion of satellite data for further classification</i></b>            | <b>17</b> |
| <b>5.0.</b>         | <b><i>Need of study</i></b>  | <b>19</b> |
| <b>6.0.</b>         | <b><i>Objectives</i></b>   | <b>20</b> |
| <b>Study Area</b>   |  |           |
| <b>7.0.</b>         | <b><i>Description of the Study Area</i></b>                                  | <b>21</b> |

|                 |  |           |
|-----------------|--|-----------|
| <b>7.1.</b>     | <b>Geographical area</b>   | <b>21</b> |
| <b>7.2.</b>     | <b>History</b>   | <b>21</b> |
| <b>7.3.</b>     | <b>Resources</b>   | <b>22</b> |
| <b>7.4.</b>     | <b>Geology</b>   | <b>22</b> |
| <b>7.5.</b>     | <b>Climate</b>   | <b>23</b> |
| <b>7.6.</b>     | <b>Flora fauna</b>   | <b>23</b> |
| <b>7.7</b>      | <b>Non Wood Forest Product (N.W.F. P.)</b>   | <b>24</b> |
| <b>7.8</b>      | <b>Tourism</b>   | <b>25</b> |
|                 | <b>Materials and Method</b>  |           |
| <b>8</b>        | <b>Data used</b>   | <b>26</b> |
| <b>8.1.</b>     | <b>Reference Maps</b>  | <b>26</b> |
| <b>8.1.1.</b>   | <b>Satellite Data</b>  | <b>26</b> |
| <b>8.1.1.1.</b> | <b>Optical Data</b>  | <b>26</b> |
| <b>8.1.1.2.</b> | <b>Microwave data</b>  | <b>28</b> |
| <b>9</b>        | <b>Ground survey</b>   | <b>31</b> |
| <b>9.1.</b>     | <b>Primary analysis</b>  | <b>31</b> |
| <b>9.1.1.</b>   | <b>Tree composition</b>  | <b>31</b> |
| <b>9.1.2.</b>   | <b>Phenology</b>   | <b>31</b> |
| <b>9.1.3.</b>   | <b>Tree structural parameter</b><br>1) DBH<br>2) Crown Cover<br>3) Height<br>4) Basal Area | <b>31</b> |
| <b>9.2.</b>     | <b>Secondary analysis</b>  | <b>33</b> |
| <b>9.2.1.</b>   | <b>Shannon-Wiener Diversity Index</b>  | <b>33</b> |
| <b>9.2.2.</b>   | <b>Margalef Index</b>  | <b>33</b> |
| <b>9.2.3.</b>   | <b>McIntosh Index</b>  | <b>33</b> |
| <b>9.2.4.</b>   | <b>Brillouin index</b>   | <b>33</b> |
| <b>9.3.</b>     | <b>Non-conventional techniques</b>   | <b>34</b> |
| <b>9.3.1.</b>   | <b>Species diversity assessment</b>  | <b>34</b> |
| <b>9.3.2.</b>   | <b>Phenological assessment</b>   | <b>34</b> |
| <b>9.3.3.</b>   | <b>Regression analysis</b>   | <b>34</b> |
| <b>9.3.4.</b>   | <b>Tree structural parameter prediction with non-conventional method</b>                   | <b>35</b> |
| <b>9.4.</b>     | <b>RS &amp; GIS Analysis</b>   | <b>35</b> |
| <b>9.4.1.</b>   | <b>Base Map preparation</b>  | <b>35</b> |
| <b>9.4.2.</b>   | <b>Village Map Generation</b>  | <b>35</b> |

|          |  |    |
|----------|--|----|
| 9.4.3.   | <i>Importing Satellite Data</i>  | 35 |
| 9.4.4.   | <i>Geo-referencing</i>   | 35 |
| 9.4.5.   | <i>Sub-setting</i>   | 35 |
| 9.5.     | <i>Microwave data processing</i>   | 35 |
| 9.5.1.   | <i>Need for speckle filtering</i>  | 36 |
| 9.5.2.   | <i>Filter used</i>   | 36 |
| 9.5.3.   | <i>Geo-referencing of microwave data</i>   | 37 |
| 9.5.4.   | <i>Sigma Nought</i>  | 37 |
| 9.6.     | <i>Estimation of Biochemical and Biophysical parameters</i>                            | 39 |
| 9.6.1.   | <i>Conventional techniques</i>   | 39 |
| 9.6.1.1. | <i>Estimation of chlorophyll content</i>   | 39 |
| 9.6.1.2. | <i>Estimation of Leaf area Index</i>   | 39 |
| 9.6.1.3. | <i>Estimation of Relative water content</i>  | 39 |
| 9.6.2.   | <i>Correlation of conventionally derived parameters with spatially derived indices</i> | 39 |
| 9.6.3.   | <i>Secondary Analysis</i>  | 40 |
| 9.6.4.   | <i>Biomass from Optical Data</i>   | 40 |
| 9.6.5.   | <i>Biomass from Microwave Data</i>   | 40 |
| 9.7.     | <i>Techniques used for Image classification</i>  | 42 |
| 9.7.1.   | <i>Supervised Classification for optical and microwave data</i>                        | 42 |
| 9.7.2.   | <i>Cloude-Pottier Decomposition</i>  | 43 |
| 9.8.     | <i>Data fusion Technique</i>   | 45 |
| 9.8.1.   | <i>Ehlers Fusion Technique</i>   | 45 |
| 9.8.2.   | <i>The Modified IHS (intensity, hue, saturation) Transformation</i>                    | 46 |
| 9.8.3.   | <i>Brovey Transform</i>  | 46 |
|          | <b>Results</b>   |    |
| 10.0.    | <i>Tree inventory</i>  | 47 |
| 10.1.    | <i>Species Composition</i>   | 47 |
| 10.2.    | <i>Species Diversity through Conventional And Non-Conventional Techniques</i>          | 49 |
| 10.2.1.  | <i>Shannon index</i>   | 50 |
| 10.2.2.  | <i>Margalef index</i>  | 50 |
| 10.2.3.  | <i>McIntosh Index</i>  | 50 |
| 10.2.4.  | <i>Brillouin Index</i>   | 50 |
| 10.3.    | <i>Non-Conventional Method</i>   | 51 |

|                |  |           |
|----------------|--|-----------|
| <b>10.4.</b>   | <b><i>Phenology</i></b>  | <b>54</b> |
| <b>10.5.</b>   | <b><i>Impact Of Phenology On Backscatter Obtained From Microwave Data</i></b>        | <b>62</b> |
| <b>10.6.</b>   | <b><i>Tree Damage</i></b>  | <b>64</b> |
| <b>10.7.</b>   | <b><i>Forest Structural Parameters</i></b>   | <b>70</b> |
| <b>10.7.1.</b> | <b><i>DBH</i></b>  | <b>70</b> |
| <b>10.7.2.</b> | <b><i>Total Height</i></b>   | <b>71</b> |
| <b>10.7.3.</b> | <b><i>Crown cover</i></b>  | <b>72</b> |
| <b>10.7.4.</b> | <b><i>Basal area</i></b>   | <b>72</b> |
| <b>10.8.</b>   | <b><i>Relationship between DBH, Total Tree Height, and Crown Cover</i></b>           | <b>73</b> |
| <b>10.9</b>    | <b><i>Correlation between DBH and Crown cover</i></b>                                | <b>75</b> |
| <b>10.10</b>   | <b><i>Predicting forest structure using Remote sensing data</i></b>                  | <b>77</b> |
| <b>11.0</b>    | <b><i>Estimation Of Biochemical And Biophysical Parameters Of Forest</i></b>         | <b>79</b> |
| <b>11.1.</b>   | <b><i>Conventional technique</i></b>   | <b>79</b> |
| <b>11.1.1.</b> | <b><i>Chlorophyll content</i></b>  | <b>79</b> |
| <b>11.1.2.</b> | <b><i>Leaf area Index</i></b>  | <b>81</b> |
| <b>11.2</b>    | <b><i>Non-Conventional Technique</i></b>   | <b>82</b> |
| <b>11.2.1.</b> | <b><i>Normalized Difference Vegetation Index</i></b>                                 | <b>82</b> |
| <b>11.3</b>    | <b><i>Correlation Of Biochemical And Biophysical Parameter With NDVI</i></b>         | <b>84</b> |
| <b>11.3.1.</b> | <b><i>Chlorophyll-NDVI</i></b>   | <b>84</b> |
| <b>11.3.2.</b> | <b><i>LAI-NDVI</i></b>   | <b>84</b> |
| <b>11.4</b>    | <b><i>Relative Leaf Water Content</i></b>  | <b>85</b> |
| <b>11.5</b>    | <b><i>NDMI-Normalized Differential Moisture Index</i></b>                            | <b>87</b> |
| <b>11.6</b>    | <b><i>Biomass</i></b>  | <b>88</b> |
| <b>11.6.1.</b> | <b><i>Generation of Biomass map through Non-conventional of Dediapada Taluka</i></b> | <b>89</b> |
| <b>11.6.2.</b> | <b><i>Biomass Estimation Using Microwave Data</i></b>                                | <b>91</b> |
| <b>11.6.3.</b> | <b><i>ENVISAT-ASAR</i></b>   | <b>91</b> |
| <b>11.7</b>    | <b><i>RADARSAT-2</i></b>   | <b>92</b> |
| <b>11.8</b>    | <b><i>ENVISAT-ASAR based Biomass Map</i></b>   | <b>94</b> |
| <b>12.0.</b>   | <b><i>Forest cover mapping</i></b>   | <b>95</b> |
| <b>12.1.</b>   | <b><i>Accuracy assessment</i></b>  | <b>97</b> |
| <b>12.2.</b>   | <b><i>Kappa statistics</i></b>   | <b>97</b> |
| <b>12.3.</b>   | <b><i>Classification of forest through microwave data</i></b>                        | <b>97</b> |

|              |  |            |
|--------------|--|------------|
| <b>12.4.</b> | <b><i>Polarimetric decomposition</i></b> | <b>98</b>  |
| <b>13.0.</b> | <b><i>Data fusion</i></b>                | <b>103</b> |
| <b>14.0.</b> | <b><i>Discussion</i></b>                 | <b>108</b> |
| <b>15.0.</b> | <b><i>Conclusion</i></b>                 | <b>130</b> |
|              | <b><i>Summary</i></b>                    | <b>133</b> |
|              | <b><i>References</i></b>                 | <b>136</b> |





| Plate No. | Title   | Pg No. |
|-----------|---|--------|
| Plate 1   | The world's forests   | 2      |
| Plate 2   | Forest area as a percentage of total land area by country, 2010         | 2      |
| Plate 3   | Study Area –Dediapada Taluka of Narmada District                        | 21     |
| Plate 4   | Shoolpaneshwar Sanctuary -Dhumkal Range                                 | 22     |
| Plate 5   | Photograph showing Teak forest  | 23     |
| Plate 6   | Photograph showing Butea forest   | 23     |
| Plate 7   | Butea monosperma flowers  | 24     |
| Plate 8a  | Wildlife of Dediapada forest  | 24     |
| Plate 8b  | Ninai Waterfalls  | 25     |
| Plate 9   | Displaying the NDVI, village and the integrated map with selected sites | 52     |
| Plate10   | Showing the different Forest Type along with Shannon diversity Map      | 53     |
| Plate 11  | Tree damage assessment carried out in Dediapada Taluka                  | 66     |
| Plate 12  | Displaying the NDVI (1990-2005) of Dediapada Taluka                     | 83     |
| Plate 13  | Estimation of NDMI from satellite data                                  | 87     |
| Plate 14  | The biomass map for year 2001 and 2005                                  | 90     |
| Plate 15  | ENVISAT-ASAR based Biomass Map  | 94     |
| Plate 16  | Forest cover map for year 1997 and 2005                                 | 95     |
| Plate 17  | Classification of Radarsat-2-2011                                       | 98     |
| Plate 18  | Classification of entropy and alpha                                     | 101    |
| Plate 19  | Comparison of Optical and Microwave data                                | 102    |
| Plate 20  | Fusion techniques using Landsat ETM+(MSS) and Landsat Panchromatic      | 105    |
| Plate 21  | Fusion techniques using LISS-III (MSS) and ENIVISAT-ASAR                | 106    |
| Plate 22  | Fusion techniques using LISS-III (MSS) and Radarsat                     | 107    |

## List of Tables

| <b>Table No.</b> | <b>Title</b>  | <b>Pg. No.</b> |
|------------------|---|----------------|
| Table A          | <i>Displaying optical data</i>  | 26             |
| Table B          | Displaying Microwave data   | 28             |
| Table 1          | <i>Tree species observed in various plots of the study area</i>                               | 47             |
| Table 2          | <i>Exhibiting diversity Indices in different Villages of Dediapada Region</i>                 | 49             |
| Table 3          | <i>A comparative evaluations of different diversity indices</i>                               | 51             |
| Table 4          | <i>Accuracy verification for Shannon</i>  | 54             |
| Table 5          | <i>Tree condition in Dediapada Taluka</i>   | 68             |
| Table 6          | <i>Sample Means for DBH, Tree Height and Crown cover</i>                                      | 73             |
| Table 7          | <i>Correlation and the Regression analysis between DBH, Total Tree Height and Crown Cover</i> | 77             |
| Table 8          | <i>Biomass obtained from Ground survey</i>  | 89             |
| Table 9          | <i>Changes in Biomass values from 2001-2005</i>   | 91             |
| Table 10         | <i>Area in Percentage change</i>  | 96             |
| Table 11         | <i>Interpretation of zones</i>  | 99             |

|          |  |     |
|----------|--|-----|
| Table 12 | Characteristic of forest cover classes   | 100 |
| Table 13 | Accuracy assessment and Kappa statistics | 103 |

### **List of Figures**

| <b>Figure No.</b> | <b>Title</b>  | <b>Pg. No.</b> |
|-------------------|---|----------------|
| Figure 1          | Types of canopy Backscatter   | 12             |
| Figure 2          | Illustration of relationship of data fusion and image fusion  | 18             |
| Figure 3          | Percentage of tree species in flowering   | 55             |
| Figure 4          | Percentage of tree species in fruiting  | 55             |
| Figure 5          | Percentage of tree species in leaf flush  | 56             |
| Figure 6          | Rainfall-Dediapada (1992 & 2007)  | 57             |
| Figure 7          | Temperature-Dediapada (1992 & 2007)   | 57             |
| Figure 8          | Phenology of Albizia lebbeck during 1992-2007   | 59             |
| Figure 9          | Phenology of Boswellia serrata during 1992-2007   | 60             |
| Figure 10         | Phenology of Butea monosperma during 1992-2007  | 61             |
| Figure 11         | Phenology of Tectona grandis during 1992-2007   | 62             |
| Figure 12         | Dediapada Backscatter in Different Months   | 63             |
| Figure 13         | Dediapada Phenology in Different Months   | 63             |
| Figure 14         | DBH across different villages of Dediapada  | 71             |
| Figure 15         | Total Height across different villages of Dediapada   | 71             |
| Figure 16         | Crown cover across different villages of Dediapada  | 72             |
| Figure 17         | Basal Area across different villages of Dediapada   | 73             |
| Figure 18         | Correlation between DBH and Total Tree Height   | 74             |
| Figure 19         | Correlation between DBH and Crown cover   | 76             |
| Figure 20         | Scatter plots and the result of regressing DBH, height, crown cover and Basal area of 30 m X 30 m ground plot | 78             |
| Figure 21         | Chlorophyll content in five different species in various seasons  | 80             |
| Figure 22         | LAI in five different species in various seasons  | 82             |
| Figure 23         | Chlorophyll content correlation with NDVI   | 84             |
| Figure 24         | Correlation between LAI and NDVI  | 85             |
| Figure 25         | Relative Water content in five different species  | 86             |
| Figure 26         | correlation of NDMI with RWC  | 88             |
| Figure 27         | Biomass correlation with NDVI   | 90             |
| Figure 28         | Relationship between Radar backscatter and Biomass  | 92             |
| Figure 29         | Biomass vs Backscatter- February-2011   | 93             |
| Figure 30         | Biomass vs Backscatter- April-2011  | 93             |
| Figure 31         | Biomass vs Backscatter- June-2011   | 94             |
| Figure 32         | Chart depicting the area statistics for the year 1997 and 2005.   | 96             |
| Figure 33         | Segmentation of entropy-alpha feature space   | 99             |
| Figure 34         | Segmentation of entropy-alpha feature space   | 100            |

### **List of flow charts**

| <b>Flowchart No.</b> | <b>Title</b>  | <b>Pg. No.</b> |
|----------------------|---|----------------|
| Flow Chart 1         | Forest Inventory  | 30             |
| Flow Chart 2         | Forest health using biochemical and biophysical parameter | 38             |
| Flow Chart 3         | Forest cover mapping using remote sensing                 | 41             |
| Flow Chart 4         | Forest Map Using Data Fusion                              | 44             |

### ***List of Illustration***

| <b>No.</b>            | <b>Title</b>                                 | <b>Pg. No.</b> |
|-----------------------|--|----------------|
| <i>Illustration 1</i> | Height measurements: trigonometric principle | 32             |
| <i>Illustration 2</i> | Basic overview of the Ehlers Fusion process  | 45             |