

LIST OF CONTENT

| | |
|---|------|
| ABSTRACT | i |
| INTISARI | ii |
| ACKNOWLEDGEMENTS | iii |
| LIST OF CONTENT | iv |
| LIST OF FIGURES | viii |
| LIST OF TABLES | x |
| LIST OF APPENDICES | xi |
| LIST OF ABBREVIATIONS | xii |
| | |
| 1. INTRODUCTION | 1 |
| 1.1 Background | 1 |
| 1.1.1 Drought and Agricultural Productivity in District of Gunungkidul, Province of Yogyakarta Special Region, Indonesia | 1 |
| 1.1.2 Indices to Assess Drought | 3 |
| 1.2 Problem Statement | 5 |
| 1.3 Objective and Research Questions | 5 |
| 1.3.1 Research Objective | 5 |
| 1.3.2 Research Questions | 5 |
| 1.4 Methodological Flowchart | 7 |
| 1.4.1 Conceptual Framework | 7 |
| 1.4.2 Methodological Framework | 8 |
| | |
| 2. LITERATURE REVIEW | 9 |
| 2.1 Agricultural Drought and Its Occurrence in District of Gunungkidul | 9 |
| 2.2 Satellite Image of MODIS TERRA “MOD09A1” for Drought Indication | 10 |
| 2.3 MODIS TERRA “MOD09A1” Images Processing | 12 |
| 2.3.1 Indices Calculation Using Formula | 12 |

| | | |
|-------|---|----|
| 2.3.2 | Smoothing (Upper Envelop) the Noise in Hyper-temporal Images Using TIMESAT | 12 |
| 2.3.3 | ISODATA (Iterative Self-Organizing Data Analysis) | 13 |
| 2.4 | Crop Growing Season of Rain-fed Paddy Field | 14 |
| 2.5 | Temporal Graph of Indices Histogram for the Rendition of Normal Condition and Anomaly Occurrence | 17 |
| 2.5.1 | Seasonal (Temporal) Graph of Indices Profile | 17 |
| 2.5.2 | Parameters of Seasonal (Temporal) Graph | 18 |
| 2.5.3 | Rendition of Normal Condition and Anomaly Occurrence from Seasonal Graph | 20 |
| 2.6 | Unit Analysis of Indices Profile | 21 |
| 2.7 | Relevant Studies | 22 |
| 3. | STUDY AREA | 24 |
| 3.1 | Location and Administration of Study Area | 24 |
| 3.2 | Soil Type | 24 |
| 3.3 | General Morphology and Geo-hydrological Condition | 25 |
| 3.4 | Climate | 27 |
| 3.5 | Agricuture in Gunungkidul | 28 |
| 3.5.1 | Rice Field Area in District of Gunungkidul | 28 |
| 3.5.2 | Cropping Calendar | 30 |
| 3.5.3 | Rain-fed Paddy Productivity in District of Gunungkidul | 31 |
| 3.5.4 | Agriculture Contribution to GRDP | 33 |
| 3.6 | Drought in District of Gunungkidul | 34 |
| 4. | MATERIAL AND METHODOLOGY | 35 |
| 4.1 | Material Dataset | 35 |
| 4.2 | Methodology | 36 |
| 4.2.1 | Material and Dataset Collection | 37 |
| 4.2.2 | MODIS TERRA “MOD09A1” Processing | 37 |
| 4.2.3 | Sampling Technique for Indices Profiling | 39 |

| | | |
|---------|--|----|
| 4.2.4 | Analysis | 43 |
| 4.2.4.1 | Indices' Values Extraction | 43 |
| 4.2.4.2 | Normal Behavior Extraction | 44 |
| 4.2.4.3 | The Identification of Seasonal Anomaly | 44 |
| 4.2.4.4 | Drought Indication Analysis | 44 |
| 4.2.4.5 | Comparative Assessment of Indices with Rain-fed Paddy Productivity | 45 |
| 4.2.4.6 | Table Calculation Display | 45 |
| 4.2.5 | Fieldwork Verification | 45 |
| 4.3 | Tools and Software | 45 |
| 5. | RESULT AND DISCUSSION | 46 |
| 5.1 | RESULT | 46 |
| 5.1.1 | Selected Samples for Indices Profile Analysis | 46 |
| 5.1.2 | Indices Profile Parameters within a PGS, Year of 2000 – 2004 | 48 |
| 5.1.2.1 | Start-End Period of the Paddy Growing Season | 49 |
| 5.1.2.2 | Day Length of the Rain-fed Paddy Growing Season | 50 |
| 5.1.2.3 | Mean Values of Indices during a PGS in 2000 – 2014 | 52 |
| 5.1.2.4 | the Minimum, Maximum, and Amplitude of Indices Values | 54 |
| 5.1.2.5 | the Green-Up Rate Values of the Indices | 56 |
| 5.1.3 | Normal Behavior & Anomaly Calculation of the NDVI and NDDI Values Profile on a Paddy Growing Season, Year 2000 - 2014 | 56 |
| 5.1.3.1 | Seasonal Values of Normal Behavior and Anomaly Calculation | 56 |
| 5.1.3.2 | Anomaly of the NDVI & NDDI by Years, by Sub-districts | 59 |
| 5.1.4 | Normal Behavior & Anomaly Values of Paddy Productivity | 60 |
| 5.1.4.1 | Normal & Anomaly Values of the Rain-fed Paddy Productivity | 60 |
| 5.1.4.2 | Anomaly Location of the Rain-fed Paddy Productivity | 62 |
| 5.1.5 | The Agricultural Drought Indication | 63 |
| 5.1.5.1 | Severity or Magnitude of Agricultural Drought in Gunungkidul | 63 |
| 5.1.5.2 | Duration of Agricultural Drought in Gunungkidul | 64 |
| 5.1.5.3 | Frequency of Agricultural Drought in Gunungkidul | 65 |

| | | |
|---------|---|----|
| 5.1.5.4 | Anomaly-Maps Representation in District of Gunungkidul | 65 |
| 5.1.6 | Comparative Assessment | 66 |
| 5.2 | DISCUSSION | 67 |
| 5.2.1 | Agricultural Drought Identification in District of Gunungkidul Using Satellite-based Indices | 67 |
| 5.2.2 | Identified Dryness Related to the Physical Condition of District of Gunungkidul | 68 |
| 5.2.3 | Challenges in Deriving the Indices Values | 70 |
| 6. | CONCLUSION AND RECOMMENDATION | 71 |
| 6.1 | Conclusion | 71 |
| 6.1.1 | Agricultural Drought: Occurrences | 71 |
| 6.1.2 | Agricultural Drought: Spatial Occurrences | 72 |
| 6.1.3 | Comparative Assessment of NDVI and NDDI with the Rain-fed Productivity | 72 |
| 6.2 | Recommendation | 73 |
| | ANNEX | 74 |
| | REFERENCES | 88 |

LIST OF FIGURES

| | |
|--|----|
| Figure 1-1 Administration Map of Gunungkidul District | 2 |
| Figure 1-2 Relationships between Indices Profile from MODIS TERRA | 4 |
| Figure 1-3 Conceptual Framework | 7 |
| Figure 1-4 Methodological Framework | 8 |
| Figure 2-1 Sequence of drought occurrence & commonly accepted drought types | 10 |
| Figure 2-2 Surface responses at different spectral ranges | 11 |
| Figure 2-3 Smoothing Effect (Before and After Applying Upper Envelop Filter) to Reduce the Noise Using TIMESAT | 13 |
| Figure 2-4 Spatial Aggregation to Simplify Mean Values from Several Pixels | 14 |
| Figure 2-5 Delay on the CGS, Derived from the NDVI Time Series | 16 |
| Figure 2-6 Temporal Graphs of NDVI Dynamic Values, Retrieved from One Pixel | 17 |
| Figure 2-7 Paddy Stage Associated to Its Greenness Condition | 18 |
| Figure 2-8 Seasonal Parameters of Indices Profile | 19 |
| Figure 2-9 Spatial Representations of the NDDI Values in District of Gunungkidul, by (a) classed-based, and (b) pixel-based | 22 |
| Figure 3-1 Soil Type Map of Gunungkidul District | 25 |
| Figure 3-2 General View of Gunungkidul Morphology | 26 |
| Figure 3-3 Geo-hydrological Map of Gunungkidul Morphology | 26 |
| Figure 3-4 Rainfall Map of Gunungkidul District | 27 |
| Figure 3-5 Monthly Rainfalls in mm (top) & of Rain Days (bottom) | 28 |
| Figure 3-6 Rain-fed Paddy-Field Area of Gunungkidul District | 29 |
| Figure 3-7 Comparison of Rain-fed Paddy Field by Sub-Districts | 29 |
| Figure 3-8 Paddy Production by Sub-district (Ton) in Gunungkidul | 32 |
| Figure 3-9 Rain-fed Paddy Productivity in District of Gunungkidul | 32 |
| Figure 3-10 Map of Rain-fed Paddy Productivity (Quintals/Hectare) | 33 |

| | |
|--|----|
| Figure 4-1 The the Indices Profiles of NDVI and NDWI, before and after filtering using TIMESAT | 38 |
| Figure 4-2 Area-extent ratio of rain-fed paddy field by its sub-districts | 40 |
| Figure 4-3 the area-extent ratio of rain-fed paddy field coverage (%), corresponds to the samples & uncovered sub-districts | 41 |
| Figure 5-1 Map of rain-fed paddy field area and the 50 sample locations | 47 |
| Figure 5-2 Mean Values of NDVI & NDDI within the 1 st & 2 nd PGS | 50 |
| Figure 5-3 Total and Mean Length of PGS on the 1 st & 2 nd Planting | 51 |
| Figure 5-4 Seasonal LOC and Change Detection of PGS on the 1 st & 2 nd | 52 |
| Figure 5-5 Mean Values of NDVI & NDDI within a PGS on the 1 st & 2 nd Planting, by Years and by Sub-districts | 54 |
| Figure 5-6 Minimum, Maximum, & Amplitude Values of NDVI, NDDI, and Its Amplitude Comparison within a PGS, 2000 – 2014 | 55 |
| Figure 5-7 Green-up rate of NDVI & NDDI within a PGS, 2000 – 2014 | 57 |
| Figure 5-8 Normal Behavior & Anomaly Values of NDVI & NDDI within PGS Over Years | 58 |
| Figure 5-9 Anomaly Values of Indices by Years by Sub-districts | 60 |
| Figure 5-10 Normal Behavior & Anomaly Values of Rain-fed Paddy Productivity, Year 2000 – 2013 | 61 |
| Figure 5-11 Rain-fed Paddy Productivity Average (Qu/Ha) and Its Field Area Extent, by Sub-districts, by Years | 62 |
| Figure 5-12 Anomaly of Rain-fed Paddy Productivity by Years, by Sub-districts | 63 |
| Figure 5-13 Anomaly Calculation of Indices and Its Change-rate Detection, by Years | 64 |
| Figure 5-14 Duration of Elongated Dryness Period within Anomaly Years | 65 |
| Figure 5-15 Annual Mean Rainfalls & Mean Rain days Compared to Annual Mean of Indices Values | 69 |

LIST OF TABLES

| | | |
|------------|---|----|
| Table 1-1. | Specific Objectives and Research Questions | 6 |
| Table 2-1 | MOD09A1 General Characteristic | 11 |
| Table 3-1 | Paddy Planting Calendar in District of Gunungkidul, year 2014 | 30 |
| Table 4-1 | Rain-fed Paddy Field Coverage (%) Corresponds to the Number of Pixels and the Uncovered Sub-District | 41 |
| Table 4-2 | Rain-fed Paddy Field Coverage (%) Corresponds to the Number of Samples | 42 |
| Table 5-1 | Values of Indices, Anomaly, and Normal Behavior, Year 2000 – 2014 | 66 |
| Table 5-2 | Rain-fed Paddy Productivity, Anomaly Values, and Normal Behavior, Year 2000 – 2014 | 67 |
| Table 5-3 | the Comparative Assessment Result Using Pearson Product Moment | 67 |

LIST OF APPENDICES

| | | |
|-----------|---|----|
| Annex 1a. | 21 Location Samples for Indices Profiling, Taken from $\geq 95\%$ Rain-fed Paddy Field Coverage in One MOD09A1 Pixel-size | 75 |
| Annex 1b. | 29 Location Samples for Indices Profiling, Taken from $\geq 70\%$ Rain-fed Paddy Field Coverage in One MOD09A1 Pixel-size | 76 |
| Annex 2a. | 21 Samples Overview for Indices Profiling, Based on $\geq 95\%$ Rain-fed Paddy Field Coverage in One MOD09A1 Pixel-size | 77 |
| Annex 2b. | 29 Samples Overview for Indices Profiling Based on $\geq 70\%$ Rain-fed Paddy Field Coverage in One MOD09A1 Pixel-size. | 78 |
| Annex 3 | Mean Values of NDVI (Green Dots) & NDDI (red dots) from 50 sample locations within a PGS, 2000 – 2014 | 79 |
| Annex 4 | Temporal images of greenness performance during The anomaly occurrence in 2005, 2007, and 2010 | 80 |
| Annex 5 | Rain-fed Paddy Productivity (Quintals/Ha) By Sub-districts, Year 1997 – 2013 | 82 |
| Annex 6 | Rain-fed Paddy Field Area in District of Gunungkidul, Province of Yogyakarta Special Region | 83 |
| Annex 7 | the Anomaly Values of NDVI & NDDI by Sub-Districts, Year 2001 – 2013 | 85 |
| Annex 8 | the Anomaly Values of Rain-fed Paddy Productivity by Sub-Districts, Year 2001 – 2013 | 86 |
| Annex 9 | Form of Verification | 87 |