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Analytical Evaluation of Meta-Heuristic Approaches For Satellite Image Classification

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***Abstract:** Satellite image classification is one of the well adapted research area in the field of satellite, space science, remote sensing and other terrain based feature applications. Its major application is in the field of robotic path planning and terrain feature extraction which further can be used for the GPS based location tracking and path planning from one place to another. In this research, concepts of nature inspired meta-heuristic have been studied for the application of satellite image classification. Meta-heuristic algorithms are approximate and usually non-deterministic. From the types of these meta-heuristic approaches, concepts of Biogeography Based Optimization, Artificial Bee Colony Optimization, Intelligent Water Drops Algorithm, Cuckoo Search, Firefly Algorithm, Particle Swarm optimization, Hybrid Ant Colony Optimization & Biogeography Based Optimization, Hybrid Firefly Algorithm & Ant Colony Optimization, Hybrid Cuckoo Search & Intelligent Water Drops Algorithm, Hybrid Cuckoo Search & Ant Colony Optimization and Hybrid Cuckoo Search & Particle Swarm Optimization has been considered. All the methods are analyzed for the dataset of Alwar region, Rajasthan based dataset. They have been analyzed to evaluate the efficiency of concept for the classification of terrain features in the form of satellite image classification. Evaluation of concept has been made with efficiency parameters of kappa coefficient and accuracy of concept.*
***Keywords:** Image Classification, Meta-heuristic Approaches, Nature Inspired Computing, Remote Sensing, Satellite*

I. INTRODUCTION

In Image Classification process, major role is played by the digital images. Digital Image Processing is a method to analyse and interpret the digital images with the help of computer machines. A positive integer which represents the relative reflectance or emittance of an object in a digital image is known as Digital Number for images [1]. For 8 bit images, the DN or digital number lies in the range 0-255. In computer the process of digital image processing is quite simple. Digital image is provided as the input for the computer, where it take one pixel of image at single time and store each pixel data for which computer is programmed. The output of these processed images can be attained in the form of another digital image that can be further used in the real life problems. There may be possibility of infinite forms in which manipulation of digital images is possible.

Image Classification can be defined as the process to classify the entire pixels of an image into different possible feature classes as per their attribute values [2]. This classification process changes the overall structure of the image as per feature class values. This classified image can be further used for various real life problems. There is the existence of a variety of methods and approaches for the categorization of image pixels into different clusters. To generate the different terrain visualization, spectral patterns based approach is mostly used pattern recognition method [3]. The process of image classification is shown in figure 1.

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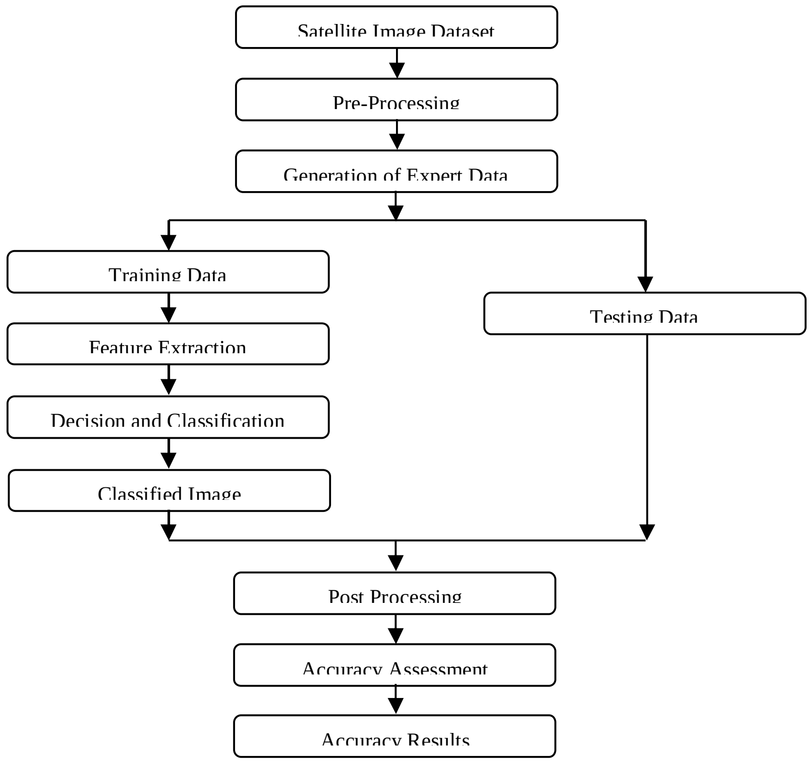

Figure 1: Process of Image Classification

In the process of image Classification, Evolved steps are Defining the Classification/feature classes, Selection of features, Sampling of training data, Estimation of Universal Statistics, Classification based on various classifiers, Verification of Results.

In Image Classification process, we emphasize to use spectral pattern recognition methods as compare to spatial pattern recognition procedures that are the directly obtained satellite data. In spectral pattern recognition methods are of two types: supervised and unsupervised approaches [4]. These are discussed as below:

In Supervised Classification, training dataset is considered to classify a particular area with required feature classes. The selection of these training samples depends upon the analyst's knowledge about the geographical place & different terrain features. Unlike Supervised Classification, Unsupervised Classification does not use the training dataset for classification process. Here some algorithms are involved to check the unknown pixels and categorize them into a set of feature classes. In unsupervised classification, no predefined samples are involved for terrain feature classification.

The organization for the other sections of paper is discussed here. Section II presents the basic concept of metaheuristic approach used for the classification; Section III present the dataset considered; Section IV gives the discussion about the experimental results and the comparison and Section V concludes the paper.

II. NATURE INSPIRED META-HEURISTIC APPROACHES

A metaheuristic approach can be defined as the higher level concept or heuristic that can be used to solve optimality problems in an iterative generation process [5]. This process guides a subordinate heuristic by combining intelligently different concepts for exploring and exploiting the search space, learning strategies are used to structure information in order to find efficiently near-optimal solutions. Metaheuristics are strategies that "guide" the search process. The goal is to efficiently explore the search space in order to find (near-) optimal solutions. Techniques which constitute metaheuristic algorithms range from simple local search procedures to complex learning processes. Metaheuristic algorithms are approximate and usually non-deterministic. Applications of Metaheuristic algorithms involve feature selection in Pattern Recognition, Automatic Clustering, Machine Learning (e.g. Neural Network Training). Meta heuristic techniques consists of approaches like single solution & multiple solution, local search & global search, memetic algorithms & hybridized approaches, nature inspired computing, parallel meta-heuristic and swarm intelligence etc. In this research work, concepts of nature inspired optimization techniques have been considered for the satellite image classification.

The considered concepts are Biogeography Based Optimization, Artificial Bee Colony Optimization, Intelligent Water Drops Algorithm, Cuckoo Search, Firefly Algorithm, Particle Swarm optimization and their possible hybrid concepts for satellite image classification.

A. Biogeography Based Optimization

The idea of Biogeography Based Optimization was first presented by Simon in 2008 [6]. Biogeography Based Optimization is also a nature inspired algorithm that is inspired by the migrating behaviour of the species as per the ecosystem. The natural process of migration of species from one island to another according to the survival circumstances is adapted for the generation of this algorithm. In BBO, the islands are considered as the solution of the problem & migration behaviour is taken as sharing of feature solutions [7]. This natural phenomenon can be used for the solution of various hard computational problems.

Biogeography can be defined as the geographical dissemination of biological species. It is the natural phenomenon that is inspired by the species to change their geographical places as per the suitable ecosystem of their habitat. In this migration process, the whole species of particular animals move from one place to another one.

B. Artificial Bee Colony Optimization

Artificial Honey Bee Optimization (ABC) is a meta-heuristic based intelligence technique inspired from the natural/social agents namely bees (Honey bees). In 2005, karaboga, has introduced the nature inspired approach of ABC to optimize the solutions of computational problems [8]. The two main properties of ABC algorithm that supports it to fit in swarm intelligence approach are collective behavior and self organizing behavior.

ABC algorithm consists of mainly two components as mentioned: Food Sources and Honey Bees. Honey bees are further categorized into three categories as mentioned: Employed Bees, Onlooker Bees and Scout Bees.

Initially, employee bees search for the random food sources and gather the useful information of landscape. Further, this landscape information has been shared with the onlooker bees which further evaluate the information by using a probabilistic approach like Roulette Wheel Method [9]. These evaluation results have further used to initiate the neighbor search. Scout bees finally exploit the available food sources with random search and determine the quality of food sources. Scout bees confirm the sugar level quality in flower patches and inform the other bees available in hives waiting for quality food source information. This communication of scout bees with other available bees is performed with “wangle dance”. With wangle dance, scout bees produce loud buzzing sound and share the information of food source quality, direction and distance of food source from hive.

C. Intelligent Water Drops Algorithm

In 2007, Hamid Shah Hosseini has analysed the behaviour of flowing water droplets in river and proposed the concept of IWD algorithm by proving a solution of TSP (Travelling Salesman Problem). Further, Hosseini has proved efficiency of concept by providing optimized solution for NP hard and NP complete problems of Multiple Knapsack Problem and N-Queen problem respectively [10]. Intelligent water droplet algorithm basically a nature inspired, population oriented approach emulated from the properties of flowing water droplets into a riverbed [11]. The key elements of IWD algorithm are velocity and soil. During its flow from the start point to end point, water droplets adapt the path with lesser soil particles and follows with increase in soil content. Linear motion based simple laws of physics can be used to calculate this time taken to cover the path from one point to another.

D. Cuckoo Search

Cuckoo Search (CS) is nature inspired optimization algorithm that came under the category of nature inspired Intelligence & introduced by Yang and Deb [12]. The optimization feature of cuckoo bird is based on the shrewd behaviour of cuckoo bird to find its solution. Cuckoo bird works individually and stores their egg in the nest of another bird’s nest by pursuing their clever behaviour. The way to lay the reproductive egg in a parasitic manner is one of the important feature of cuckoo bird. There may be chances to strike by other bird if the host bird found the different egg in their nest, then the host bird can destroy the egg. So, the main focus of cuckoo bird is to find the optimized solution that can easily match their living environment and this can be easily completed by the notion of random walk of Lévy flight. In the end, best optimized solution match is found as per the problem.

E. Firefly Algorithm

Firefly algorithm is nature intelligence based metaheuristic algorithm introduced by Xin-She Yang by taking the inspiration from the biological lighting behavior of social species firefly [13]. There is the existence of thousand of firefly species in the world and all these species are produce some rhythmic light flashes. Each firefly species follows some different pattern of flashes by using the bioluminescence process. There are some fundamental aspects behind this flashing of firefly species like protective warning mechanism, mating process and potential to attract prey. The objective function of this firefly algorithm is formulated in association with flashing light behaviour [14]. Firefly algorithm mainly depends upon three idealized rules as mentioned below.

1) One firefly attracts other apart from of their sex as all the considered fireflies are assumed as of unisex feature.
2) Fireflies attract each other depending upon their brightness. Brightness value is proportional to attractiveness. So, brighter firefly attracts the lesser brighter firefly. In case there is no possibility of brighter one, then fireflies move randomly.
3) Landscape of objective function is considered to determine the brightness of firefly algorithm.

F. Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a nature inspired technique that came in existence by the optimization behaviour & sharing behaviour of the population of the flying birds is proposed by Kennedy [15]. In Particle Swarm Optimization, particles are considered as the flock of birds that are the main agents of the optimization techniques. The two main optimization factors of this technique are local search and global search optimization features. In local search, particles get their own individual best optimized solution using their own experiences. In global search, the experience of one bird is shared with the experience of another bird and finally gets result as a global best solution.

This algorithm works in an iteration manner and moves closer to the best solution. Initially particles begin the process by the casual fly in the form of population of *N* particle solution. In the S-dimensional space, the position of the *i*th particle is represented as a point in this space where S is the number of variables participated. In the entire process, particles try to find the global best solution.

G. Ant Colony Optimization

Ant Colony Optimization is a meta-heuristic based technique introduced by Marco Dorigo for the optimization of the hard problems. Ant Colony Optimization is the based on the social behaviour of the optimization based on the ants that work in local and global experience sharing behaviour [16]. In ACO, ants use a substance name pheromone to share their experience with the path of other ants. Ant Colony Optimization is an iterative algorithm mostly used for the purpose to find the shortest optimized path with the help of several iterations. A number of ants travel from their nests in search of food in each iteration.

In ACO, proposed by Margo Dorigo, a number of artificial ants build solutions to an optimization problem and exchange information on the quality of these solutions via a communication scheme that is reminiscent of the one adopted by real ants. Ant Colony Optimization is an iterative algorithm. In each iteration, a number of ants travel from their nests in search of food. In order to find the shortest path on graph it takes the help of its pheromone count and sharing behaviour. At the end of an iteration, on the basis of the quality of the solutions constructed by the ants, the pheromone values are modified in order to bias ants in future iterations to construct solutions similar to the best ones previously constructed.

These ants deposit same amount of pheromone on their paths in order to mark some favourable path that should be followed by other members of the colony, so shorter paths will receive more pheromone per time unit. In addition, the amount of pheromone on each path decreases as time passes because of evaporation. Therefore, longer paths lose their pheromone intensity and become less favourable over time.

III. DATASET CONSIDERED

For experimentation, dataset of northern Indian region Alwar has been considered. This region is situated in Rajasthan state at latitude of 27º34’ North and longitude of 76º31’ East. With the help of Canadian and LISS-III satellites, digital images of 472*546 pixels have been captured. In this dataset, 7 different bands of satellite images are available. Radarset-1 (RS1) and Radarset-2 (RS2) band images are captured with Canadian satellite. RS1 and RS2 are further processed and Digital Elevation Model (DEM) has been generated. Here, DEM is also considered as a satellite band image. Another four band images are Near Infrared (NIR), Middle Infrared (MIR), Green and Red are captured with the help of LISS-III satellite. Satellite images captured with Canadian and LISS-III satellite are shown in figure 2 and 3 respectively.

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These satellite band images further processed to generate the pixel values for all the available bands with the help of field expert. On the basis of latitude and longitude values, expert has generated the pixel values for all the 7 bands. These generated pixels values based on latitude & longitude are further converted with respect to (x,y) coordinate of image. This reference expert data with respect to (x,y) pixels is further used as ground truth. A reference snapshot of some random pixels band values is shown in figure 4.

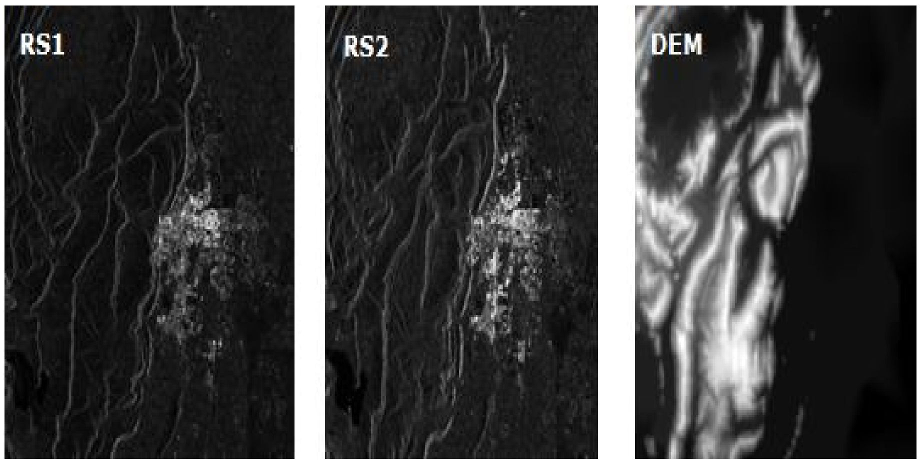


Figure 2: Band Images Captured with Canadian Satellite

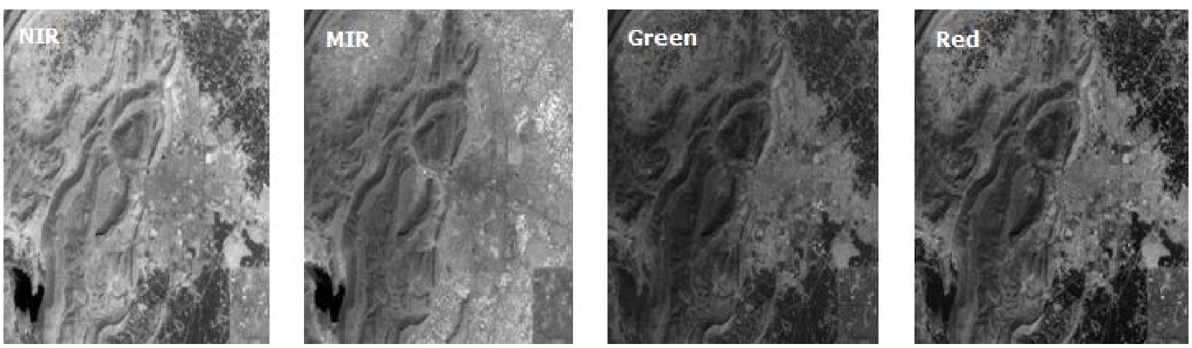
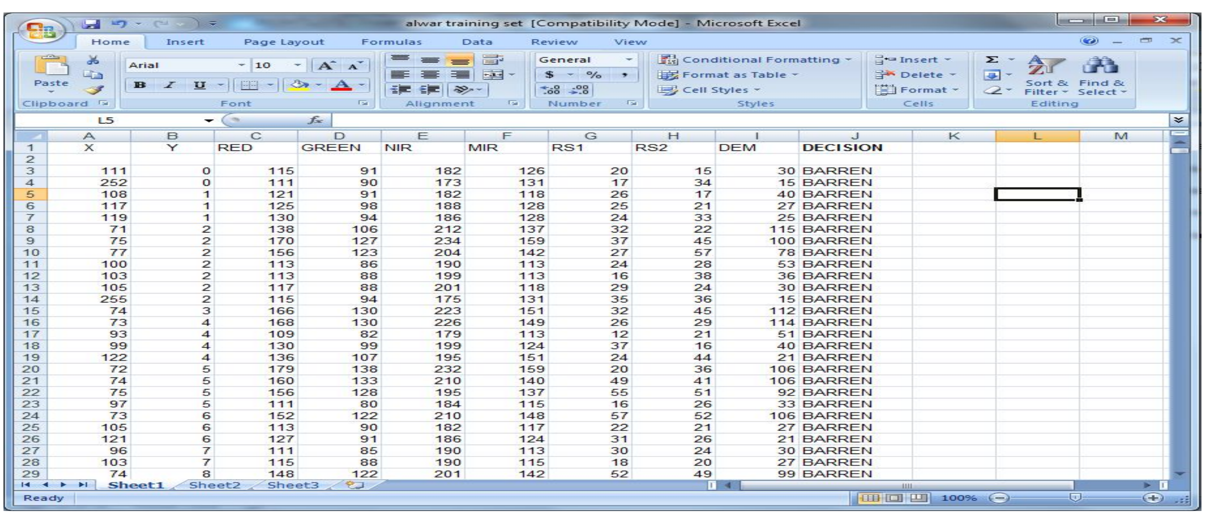


Figure 3: Band Images Captured with LISS-III Satellite



X	Y	RED	GREEN	NIR	MIR	RS1	RS2	DEM	DECISION
111	0	115	91	182	126	20	15	30	BARREN
252	0	111	90	173	131	17	34	15	BARREN
108	1	121	91	182	118	26	17	40	BARREN
117	1	125	98	188	128	25	21	27	BARREN
119	1	130	94	186	128	24	33	25	BARREN
71	2	138	106	212	137	32	22	115	BARREN
75	2	170	127	234	159	37	45	100	BARREN
77	2	156	123	204	142	27	57	78	BARREN
100	2	113	86	190	113	24	28	53	BARREN
103	2	113	88	199	113	16	38	36	BARREN
105	2	117	88	201	118	29	24	30	BARREN
255	2	115	94	175	131	35	36	15	BARREN
74	3	166	130	223	151	32	45	112	BARREN
73	4	168	130	226	149	26	29	114	BARREN
93	4	109	82	179	113	12	21	51	BARREN
99	4	130	99	199	124	37	16	40	BARREN
122	4	136	107	195	151	24	44	21	BARREN
72	5	179	138	232	159	20	36	106	BARREN
74	5	160	133	210	140	49	41	106	BARREN
75	5	156	128	195	137	55	51	92	BARREN
97	5	111	80	184	115	16	26	33	BARREN
73	6	152	122	210	148	57	52	106	BARREN
105	6	113	90	182	117	22	21	27	BARREN
121	6	127	91	186	124	31	26	21	BARREN
96	7	111	85	190	113	30	24	30	BARREN
103	7	115	88	190	115	18	20	27	BARREN
74	8	148	122	201	142	52	49	99	BARREN

Figure 4: Snapshot of Reference Dataset Pixels

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Further, these satellite images are stacked together by using ERDAS software to generate a Alwar region image with specification if available feature attributes. This stacked image is presented in presented as figure 5 with standard geological colors of available attributes as mentioned: Vegetation is represented with red color, Barren is represented with white/steel blue color, Water is represented with dark blue color, Rocky area is represented with brown color and urban area is represented with light blue/cyan color.

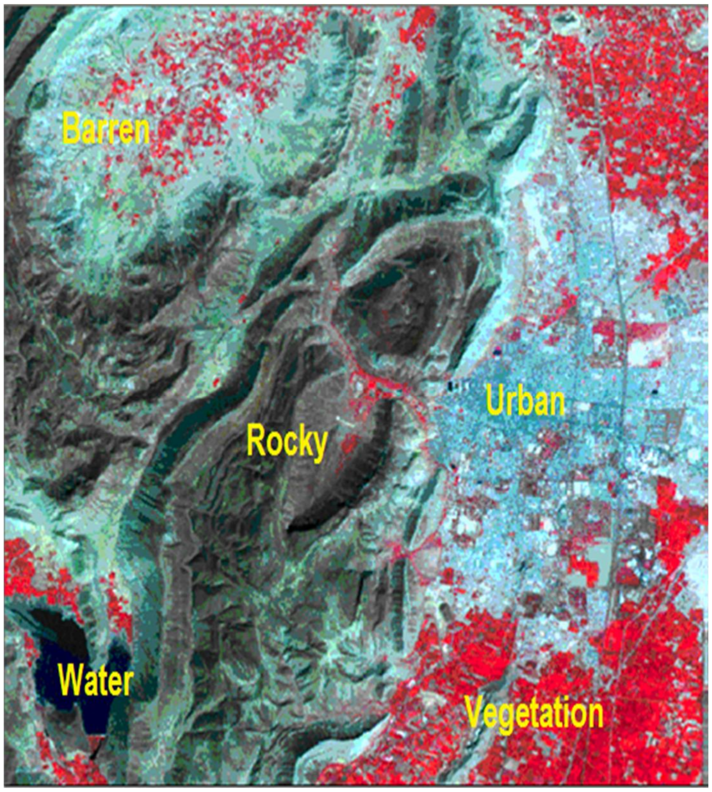

Figure 5: Stacked Alwar Image with Feature Attribute Specification

IV. COMPARITIVE ANALYSIS

Using the above dataset, results of different possible dataset have been evaluated. Correlation Matrices are used to evaluate the parameters of accuracy in terms of kappa coefficient and overall accuracy. Here, the evaluated values of all these parameters are presented.

A. Overall Accuracy

Overall accuracy is the summation of correctly classified pixels available in diagonal elements divided by the overall samples considered for evaluation. The formulation for the calculation of overall accuracy is below.

$$O = \frac{\text{Total number of correct classifications (Sum of all values on major diagonal)}}{\text{Total number of classifications}}$$

Overall Accuracy of Different concepts Biogeography Based Optimization (BBO) [20], Artificial Bee Colony Optimization (ABC) [22], Intelligent Water Drops Algorithm (IWD) [18], Cuckoo Search (CS) [19], Firefly Algorithm (FA) [17], Particle Swarm Optimization (PSO) [21], Hybrid Ant Colony Optimization (ACO) & Biogeography Based Optimization (BBO) [24], Hybrid Firefly Algorithm (FA) & Ant Colony Optimization (ACO), Hybrid Cuckoo Search (CS) & Intelligent Water Drops Algorithm (IWD) [18], Hybrid Cuckoo Search (CS) & Ant Colony Optimization (ACO) [23] and Hybrid Cuckoo Search (CS) & Particle Swarm Optimization (PSO) [24] are 75.80%, 93.47%, 89.98%, 95.78%, 91.41%, 80.34%, 81.41%, 94.63%, 96.72%, 95.55%, 97.15% respectively. This Overall accuracy based comparative analysis is shown in figure 5.

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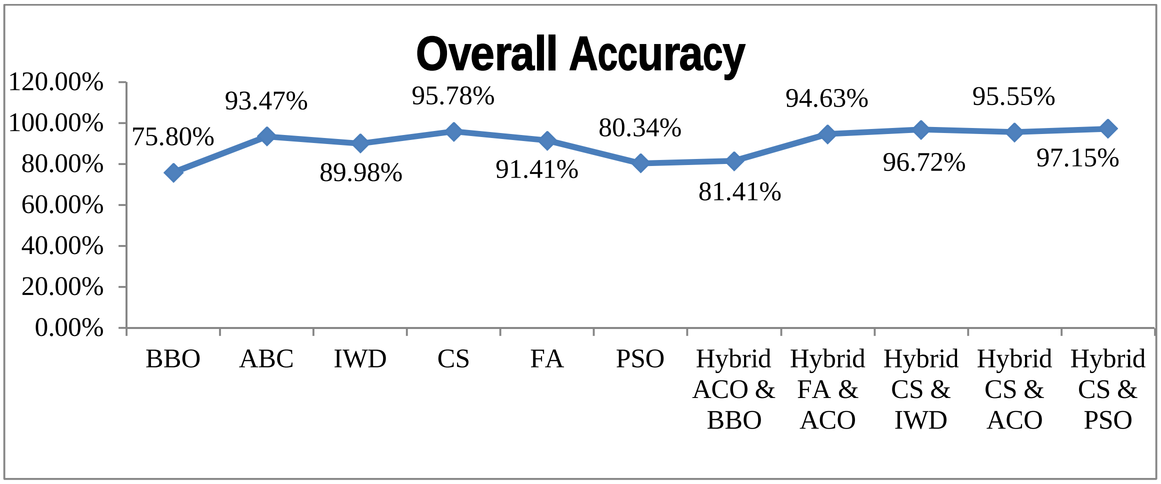

Figure 5: Overall Accuracy based Comparative Analysis

B. *Kappa Coefficient*

Kappa coefficient is a statistical parameter used to evaluate the results from correlation matrix. It also ensures the betterment of classification results with correlation matrix instead of any random evaluation. Unlike overall accuracy, kappa coefficient considers the commission and omission errors. It is also an efficient evaluation approach in case of any alike matrices but significantly unalike. It can be evaluated as formulation given in equation.

$$\hat{k} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \ldots x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \ldots x_{+i})}$$

Kappa Coefficient of Different concepts Biogeography Based Optimization (BBO), Artificial Bee Colony Optimization (ABC), Intelligent Water Drops Algorithm (IWD), Cuckoo Search (CS), Firefly Algorithm (FA), Particle Swarm Optimization (PSO), Hybrid Ant Colony Optimization (ACO) & Biogeography Based Optimization (BBO), Hybrid Firefly Algorithm (FA) & Ant Colony Optimization (ACO), Hybrid Cuckoo Search (CS) & Intelligent Water Drops Algorithm (IWD), Hybrid Cuckoo Search (CS) & Ant Colony Optimization (ACO) and Hybrid Cuckoo Search (CS) & Particle Swarm Optimization (PSO) are 0.68812, 0.917, 0.8723, 0.9465, 0.8911, 0.7033, 0.7636, 0.931, 0.9579, 0.9422, 0.9633 respectively. This kappa coefficient based comparative analysis is shown in figure 6.

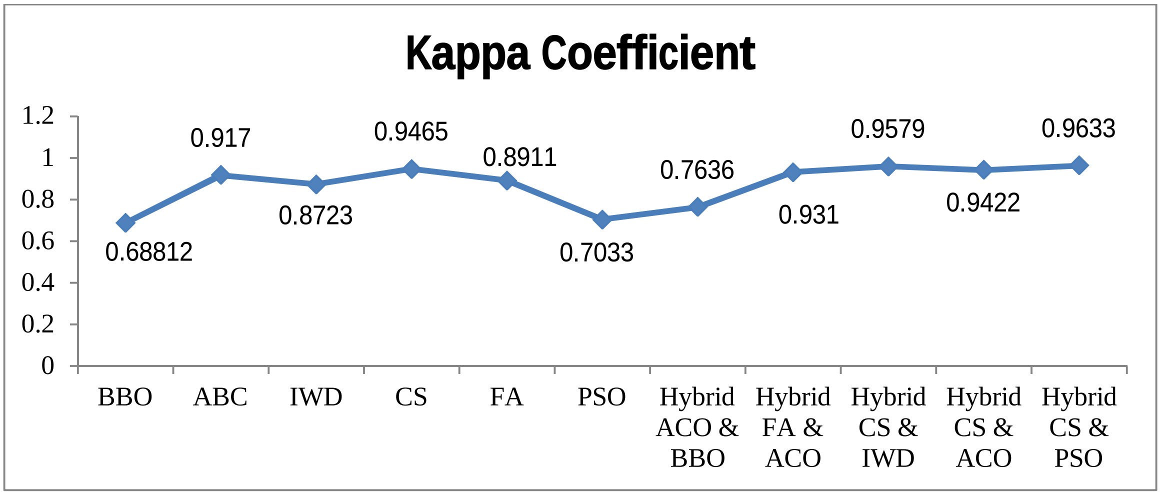

Figure 6: Kappa Coefficient based Comparative Analysis

V. CONCLUSION AND FUTURE SCOPE

In this paper, meta-heuristic based Biogeography Based Optimization (BBO), Artificial Bee Colony Optimization (ABC), Intelligent Water Drops Algorithm (IWD), Cuckoo Search (CS), Firefly Algorithm (FA), Particle Swarm Optimization (PSO), Hybrid Ant Colony Optimization (ACO) & Biogeography Based Optimization (BBO), Hybrid Firefly Algorithm (FA) & Ant Colony Optimization (ACO), Hybrid Cuckoo Search (CS) & Intelligent Water Drops Algorithm (IWD), Hybrid Cuckoo Search (CS) & Ant Colony Optimization (ACO) and Hybrid Cuckoo Search (CS) & Particle Swarm Optimization (PSO) have been compared for remote sensing image classification of terrain. The comparison was absolute accuracy level. Absolute accuracy is calculated by the overall accuracy and Kappa coefficient parameters as shown by figure 5 and figure 6 respectively. From all of above discussion, it has been analyzed that Hybrid Cuckoo Search and Particle Swarm Optimization gives better results in perspective of absolute accuracy level. From the evaluated results, it can be suggested to use this hybridization concept can be used for other application to obtain the optimum level accuracy.

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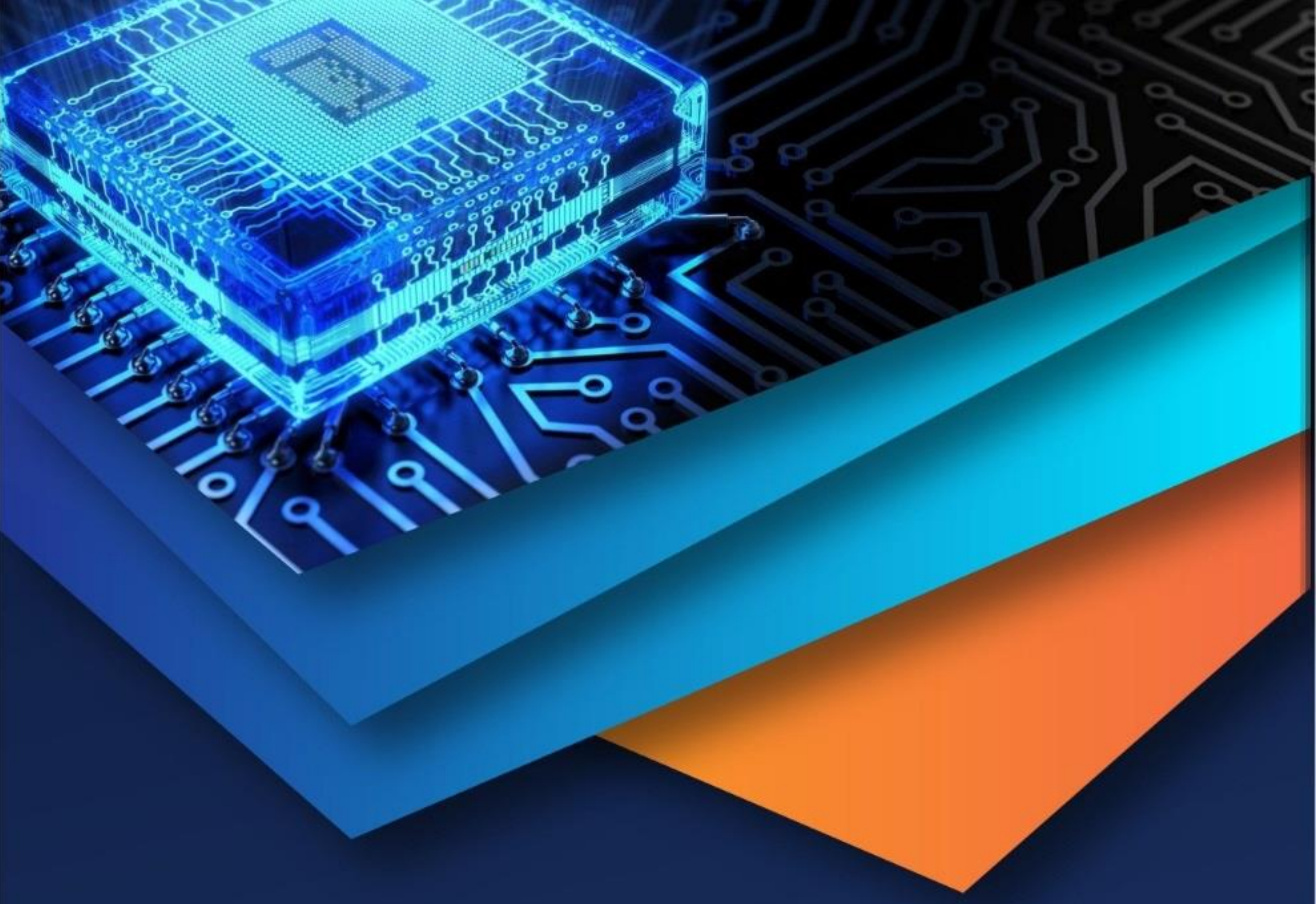

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