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HPC - A Benediction for Agriculture

Goldi Misra, Nisha Kurkure, Abhishek Das, Shweta Das and Abhinav Gupta

Centre for Development of Advanced Computing, Pune, India

Abstract. Civilization started with agriculture. India is the seventh largest country in the world in terms of its geographical size and second most populous nation in the world. Agriculture is the principal means of livelihood for half of India's population. This paper begins with a look at status of agriculture in developing country. The paper then explores some features of agriculture and then looks at how geo-information science can improve upon the former using High Performance Computing (HPC) which uses supercomputers and computer clusters to solve advanced computation problems like agricultural activity monitoring. Climate change is also making farming more difficult. The paper also discusses the weather related application which can contribute to agriculture. Finally, the paper looks at some of the open source geo information applications which make use of HPC for a sustainable agriculture. A brief conclusion is then offered as to what the paper has ultimately uncovered.

Keywords: HPC, sustainable agriculture, open source, geo information system, and supercomputer.
"Agriculture not only gives riches to a nation, but the only riches she can call her own" - Samuel Johnson.

1. Introduction

As a highly complex process, the Neolithic Revolution or the first agriculture revolution [11] marked the transition from hunting and gathering to agriculture and settlement. This paved the way for creation of societies which were more or less stationary and hence sedentary. However, after subsistence farming was replaced by mass farming the farmer mass produced food for society. Today, India ranks second worldwide in farm output. Agriculture provides the principle means of livelihood for half of India's population while contributing almost a fifth of total gross domestic product. In general, the prevailing agriculture methodologies applied in India do not produce efficient yield of agriculture commodities. Poorly maintained irrigation systems and almost universal lack of good extension services are among the factors responsible. Embarking upon this new century, one should consider how advisable it is to continue along our present technological path for agricultural development – simply doing 'more of the same' – or whether one should be moving in some other directions. The agricultural patterns that were practiced in the latter half of 20th century were termed as "Modern Agriculture". Still the pace is not sufficient and is not being fully utilized to satiate the hunger of our burgeoning population.

1.1. Features of agriculture

The Indian agriculture which is main occupation of more than 50% of the population has the following aspects:

Mechanization

Since the beginning of agriculture, all stages of agriculture were implemented manually viz. ploughing of soil, threshing with a flail etc. Upon the end of the subsistence farming, the farmer and the farm were under pressure to maximize agriculture production. The use of machines and technology created a great positive impact in the field of agriculture. For example: The Haber-Bosch method for synthesizing ammonium nitrate created a major breakthrough which greatly increased crop production.

Genetic Manipulation

In the Modern agriculture extensive and successful efforts were made to breed plants and get a better yield. New varieties of crops accelerated productivity growth in agriculture. Genetic engineering using highly sophisticated techniques is heralded as creating new opportunities for agricultural productivity enhancement that are not attainable by conventional breeding methods.

Globalization

Mechanization and Genetic Manipulation, have raised the standards of agriculture output viz. tractors have increased the area of arable land; breeding has increased the quality and productivity of the crop. It forms the basis of many premier industries which has opened doors to international market adding to the country's economy.

1.2. Challenges Confronting Indian Agriculture

Though the above mentioned features stand as a pillar to the country's agriculture; still the crop production faces few issues. Climate change is the greatest limitation making farming more difficult. Climate change has the potential to negatively impact agriculture due to drastic changes in temperature, rainfall, CO2, solar radiation and the interaction of these elements. The world's agricultural systems rely substantially on increasing use of fertilizers. But now, the world's farmers are witnessing signs of a declining response curve, where the use of additional fertilizer yields little additional food product. At the same time, fertilizers and intensive cropping lower the quality of soil. Pesticide use has increased, yet crop loss from pests has remained relatively constant. Eutrophication leads to loss of biodiversity. Land transformation and degradation also limits the annual cultivation of crops.

2. HPC and Agriculture

The need of the hour is not application of the technology but the adoption of appropriate technology, which would suit the particular level of the global community. Today, there is a growing need for the power of high performance computing. Due to rapid growth in high performance computing it has become a key technology which is driving the future research and development activities. Agriculture field has lots of scope to improve and use HPC. HPC solutions help to focus on internal resources, energy and time on the research that will help to achieve goal. It divides the problem into small fragments and after that different processors helps to find out the solution of different part by using algorithms known as parallel processing algorithms and required software's. Therefore the problem with huge computation which takes ample amount of time serially can be done at the earliest using HPC. Supercomputing Facility allows the estimation of the large, globally convex, flexible agricultural production system. Agriculture is closely associated with data analysis. In agriculture the nature of soil, climatic changes play an important role. Using HPC we can analyze minute details of soil and climate, which will increase the yield of crop exponentially. HPC makes possible the microscopic analysis of the soil and climate. This plays a decisive role in exponentially increasing the crop yield.

Whenever an agriculture research involves a large land area, satellite imagery is vital. However, the use of satellite imagery in agrarian research has its own set of limitations. But it cannot capture the minute details related with the crop and soil where simulation models can assist which computes a huge amount of data to present the final result. This computation requires fast processing speed and a database to store the large amount of output generated where in HPC works.

Thus, the challenge confronting Indian agriculture is to obtain information about non-visible data viz. soil characteristic, ground water depth [6].

3. Geographic Information System

Geographical information system is a system designed to capture, store, manipulate, analyze, manage and present all types of geographically referenced data [10]. In India, the farming practices are too haphazard and non-scientific and hence need some forethought before implementing any new technology.

Ignorance of variations in soil fertility and crop conditions across the field by the agricultural applications do not yield desirable results as applications take uniform rates of inputs. To improve the crop

production and minimizing the environmental impact on crops, managing the variations in soil fertility and crop conditions across the field is required.

Thus, the information on spatial variability in soil fertility status and crop conditions is a pre-requisite for adoption of precision farming [4]. Geographical information system (GIS) holds good promise in deriving information on soil attributes and crop yield, and allows monitoring seasonally- variable soil and crop characteristics, namely soil moisture, growth, nutrient deficiency, crop disease, and weed and insect infestation, which, in turn, help in optimizing inputs and maximizing crop yield and income.

This paper describes few Open Source HPC based GIS applications used to sort and solve some of the above mentioned issues.

3.1. Grass

Geographic Resource Analysis Support System commonly referred as GRASS is free open source software used for geospatial data management and analysis, image processing, graphics/maps production, spatial modelling, and visualization [5] of many types of data. One of the main challenges facing India was producing enough food for the rapidly increasing population. As not more than the existing land is fit for cultivation, India has to strive to develop productivity on existing land. The total arable land is completely under cultivation. GRASS also assists in locating the fertile land parts.

The test case consists of a sample data set which when fed to GRASS shows following output.

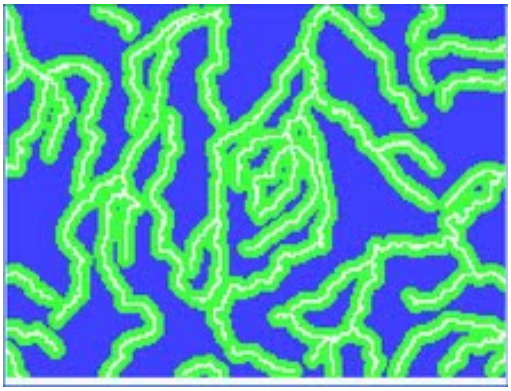

Fig. 1: Image showing underground Streams

Fig. 1 explains the streams running underground which helps in making efficient use of canal paths.

TABLE 1

Deforestation	Fuel Wood	Over Grazing	Agriculture	Industrialization
40	6	26	27	-

Soils can degrade without any loss of soil particles, but always due to farming practices [7]. In TABLE 1, the five most common reasons for soil degradation are given for Asia. Actual erosion of the soil often follows the initial period of degradation.

Fig. 2 explains the soil erosion of a particular area where, the red colour indicates the highly erodible soil, yellow colour indicates medium erodible soil and green indicates low erodible soil. By having the knowledge of erosion preventive measures can be taken in advance according to the cultivation area. With in-depth knowledge of the causes of soil erosion and its pattern, preventive measures can be applied.

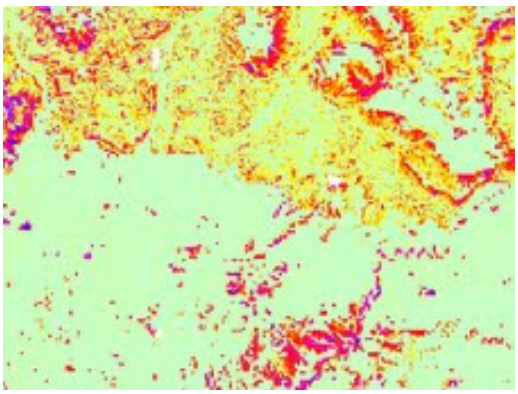

Fig. 2: Image showing Soil Erosion

3.2. Saga

System for Automated Geo-scientific Analyses (SAGA) is open source hybrid GIS software with a special "Application Programming Interface" for geographic data processing. The SAGA API supports grid data like digital terrain models and satellite images, vector data, and tables [8].

Most plants take nitrogen from the soil continuously throughout their lives and nitrogen demand usually increases as plant size increases. A plant supplied with adequate nitrogen grows rapidly and produces large amounts of succulent, green foliage. Providing adequate nitrogen allows an annual crop, such as corn, to grow to full maturity, rather than delaying it. A nitrogen-deficient plant is generally small and develops slowly because it lacks the nitrogen necessary to manufacture adequate structural and genetic materials. Older leaves often become necrotic and die as the plant moves nitrogen from less important older tissues to more important younger ones. Fig. 3 explains the utilization of nutrients by various crops.

Crop	Yield Per Acre	N	P_2O_5	K_2O	Mg	S
Alfalfa	8 tons	450	80	480	40	40
Corn	180 bu.	240	100	240	50	30
Coastal Bermuda	10 tons	500	140	420	50	40
Soybeans	60 bu.	324	64	142	27	25
Wheat	80 bu.	134	54	162	24	20

(Source: PPI)

Fig. 3: Utilization of Nutrients by various Crops

SAGA helps in simulation of dynamic processes where one can calculate nitrogen distribution which is one of the main constituent of crops, erosion and landscape development. SAGA also features Terrain Analysis, Image classification and also has a support to many of the data sets.

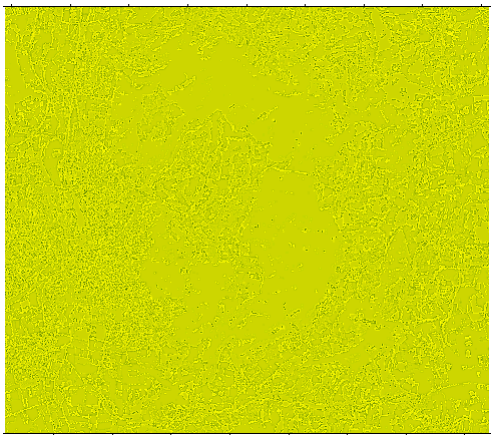

Fig. 4: Modelling of Nitrogen using SAGA

A spatially distributed nitrogen simulation (DNS) model is incorporated in SAGA to simulate daily nitrogen concentration variation. The model can simulate hydrological processes and various nitrogen processes at the grid cell level, continuously considering plant uptake, atmospheric wet deposition, fertilizer application, mineralization, nitrification and de-nitrification.

4. Weather Application

Solar radiation, temperature, and precipitation are the main drivers of crop growth. The role of climate as a determinant of agriculture has long been recognized. As discussed above, climate change is the greatest limitation making farming more difficult. The immediate problems that farmers face relate to intra-seasonal variability of rainfall, extreme events and unseasonable rains. These aberrations cause heavy losses to the crops every year [9].

There are some weather related applications which can be used to predict the climatic changes in advance. This enables the farmer to take necessary action. A HPC wire article “Supercomputer Feeds Smart Irrigation Systems” [3] illustrates this by explaining the conditions where, using HPC automatic adjustment of daily watering to crops according to the weather conditions was controlled which helps to avoid wastage of water.

Weather Research and Forecasting (WRF) is one of such parallel open source application which can be used and implemented. Weather predicting applications are compute intensive applications. The result of a test run of WRF when run serially and in parallel is given in TABLE 2.

TABLE 2

RUN	Time in Minutes
Serial	75
Run using HPC	36

TABLE 2 demonstrates that the computational time is largely reduced using HPC.

5. Conclusion

Agricultural production is very much dependent upon environmental variables and is also an important agent of environmental change. This Paper considered the subject of sustainability of Agriculture, which is an inherently 'fuzzy' problem with innumerable grey areas due to the arbitrary and intangible nature of the term ‘sustainable’. It involves complex issues such as timeframes, differing scales in space and levels of permanence. HPC provides an integrated, flexible, scalable and easy-to-use problem solving environment for Agriculture. Improved irrigation techniques provided by HPC have the potential to increase crop production. HPC also helps in Improved farming techniques in areas that rely on rainfall also could improve yield. Improving the use of fertilizer, especially on rain fed land, also would help production. Climate change will affect agriculture in different regions of the India in different proportions.

Some factors that will play an important role are the degree of temperature increase, its geographic distribution, precipitation patterns, radiation and other climate parameters. To resolve the environmental issues associated with the farm, a strategy must be developed to enforce rehabilitation of abandoned quarries where HPC can play a better role. There is a growing need to exchange knowledge and experience at various levels. In any framing and execution of a plan for agricultural reconstruction, we should bear in mind the tragic fact that so far no attempt has been made to keep the farmer in continuous touch with the work of the research institutions and to help him in all practicable ways to apply the results of research on his farm. The aim of the HPC for the agricultural sector should be directed towards providing agricultural support services to farmers in order to ensure sustainable management of agricultural resources and sustainable agricultural development.

6. Future Work

Agriculture is closely associated with data analysis. In agriculture the nature of soil, climatic changes play an important role. Using HPC we can analyze minute details of soil and climate, which will increase the yield of crop exponentially. The HPC infrastructure can be a platform for various application scaling environments in agricultural areas. For future aspects:

Planning to integrate high end applications and tools, dealing with crucial parameters viz. soil properties, water contents, fertilizers etc under a package.
The portal will include the tool for Area/Region specific Weather Forecasting.
This portal will also provide the solutions of many agriculture problems under one roof.

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