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REVIEW

(Re) Imagining the Intra-connections in Geography Education through the Notion of Place

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ABSTRACT

One of the challenges facing geography educators at higher education institutions in South Africa is to prepare students by providing them with an integrated conceptual and pedagogical toolkit that would adequately equip them to teach a type of geography that is current and relevant to local (but also global) environmental and social phenomena. As an intra-disciplinary science, Geography offers multiple avenues for fostering this type of integration, yet as argued elsewhere, [1] because of a fragmented school Geography curriculum, teacher educators struggle to foster holistic and integrated learning among novice student teachers. In fact, academic geographers most often privilege their own field of specialisation rather than work towards integration [2]. Ultimately, this perpetuates a fragmented teaching practice and conceptual understanding of geographical phenomena. This paper provides a theoretical exploration to demonstrate how Geography Education could retain its holistic nature and advance integration by (re)turning to its own intra-disciplinarity. It was found that the notion of "place" (one of Geography's big ideas) could serve as a potential point of departure for fostering integrated thinking in the discipline. The argument is made that place-based approaches offer fertile avenues to pursue in Geography Education programmes for equipping student teachers with a holistic conceptual and pedagogical toolkit.

1. Introduction

Although various reasons could be offered to explain the fragmented nature of teaching and learning in Geography, one of these could be Geography lecturers' over-emphasis on their own area of specialisation, which manifests in their teaching and research. This tendency might exacerbate fragmented thinking among student teachers who chose Geography as one of their majors. Another reason could be the inclination among geographers to look beyond their own discipline for opportunities to strengthen the discipline [3] without realising the potential of Geography's own intradisciplinary nature. This paper argues that integrated teaching, learning and thinking should already start at the levels of primary and secondary education. Thus, the paper evinces a strong focus on education at school level.

In a paper on the advancement of Geography Education (GE) in Southern Africa, some of the key challenges facing GE in South Africa, ranging from the state of school Geography and teacher education to the strength of its scholarly voice in academia is outlined [4]. The author fur-

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ther points out that GE in South Africa is defined by large discrepancies in terms of performance levels of learners in relation to national curriculum standards, the teaching and learning methods implemented by teachers, and teacher knowledge, among others [4]. Furthermore, analyses of the NSC Examination Diagnostic Report for Geography[1] 2015/6 showed that the same problems recurred. Some of these entailed the candidates' lack of conceptual understanding of geographical terminology and basic relational thinking about geographical phenomena [5]. Although various causes for this can be offered – for example, the outmoded views of knowledge according to which educational institutions including schools still operate –some scholars [1] trace part of the problem back to the two separate Geography papers that are written at the end of Grade 12; they argue this is a direct outcome of the segmented representation of content in the current Curriculum Assessment and Policy Statement (CAPS).[2] For example at the end of grade 12 learners are expected to write Paper 1 comprising of the human and physical sciences and Paper 2 which contains the map work and GIS (geographical skills). The separation of Papers 1 and 2 not only influences the type of pedagogies and their implementation, but also perpetuates a kind of "fragmented" thinking among students [1].

This paper expands on and explores this narrative of fragmentation in an attempt to return to Geography's intra-disciplinarity through focusing on the notion of place, which can strengthen integration in geographical topics as set out in the CAPS for Grades 10-12. The paper is divided into three main sections: (1) methodological approaches; (2) results and discussion and (3) implications. The results and discussion section is comprised of six sub-sections; first results from a document analysis of the Geography CAPS for the Further Education and Training (FET) phase are presented to demonstrate how topics could be more closely aligned (integrated); secondly observations gathered from teaching Geography on a BEd programme [3]will be discussed; thirdly the purpose of academic geography and geography education is presented to determine whether the content contained in the CAPS corresponds to Geography's broader purpose; and fourthly the notion of fragmentation is explored. This is followed by a discussion on the notions of intra-disciplinarity and place[4] as potential avenues for addressing the issue of fragmentation. The last sub-section presents the conceptual links or intra-actionality between *geography, place and education*. In conclusion, some implications for geography educators are discussed.

2. Methodological Approaches

The research methodology underpinning this paper is a qualitative theoretical exploration. Qualitative research is a unique way of conducting a study that requires specific ways of asking questions and thinking through a problem [6]. According to qualitative researchers, [7] method implies the manner and tools for data collection ranging from asking questions, reading documents or observing particular situations. Document analysis and observations from my own experience and position as a Geography educator are used as qualitative research methods and points of reference. The document that has been analysed qualitatively in this study is the Geography Curriculum Assessment Policy Statement (CAPS) for the Further Education and Training Phase (FET) for Grades 10-12, which is currently being used in South African public schools [8]. A qualitative content analysis was conducted on the content of the geographical themes presented from Grades 10 to 12 in order to identify whether and how any of them could be integrated more profoundly by means of the concept of place. Furthermore, inferences from observations from a group of first year teacher students are also discussed. The qualitative analyses consisted of the following steps:

(1) Identifying related topics which could have been integrated as one topic in the CAPS document;

(2) Exploring these topics in relation to different understandings/dimensions of place as a means to foster integration in Geography (Education).

(3) Observations from first year BEd students in the Geography classroom.

3. Results and Discussions

3.1 Document Analysis: Segmented Themes in the Geography CAPS (FET Phase)

This sub-section will discuss the manner how key geographical concepts feature as isolated entities in the CAPS for the FET phase (Grades 10-12), which could be considered as a possible cause for fragmented teaching and un-

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[1] This is a summary and analysis of learner performance for each question in both papers written at the end of Grade 12.

[2] The acronym CAPS stands for Curriculum Assessment Policy Statements. The document is a national policy set out by the Department of Education which states what should be included in the curricula of schools for each grade in South Africa as well as how it is to be tested or assessed.

[3] BEd programme refers to the four year degree: Bachelor in Education.

[4] For the purpose of this article the notions of place theory, place-based education and a pedagogy of place are used interchangeably.

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derstanding of geographical phenomena. The fundamental concepts of *sustainability, environment* and *place* feature widely in academic as well as in school Geography [9]. However, through a document analysis it was found that these concepts are represented as isolated, disconnected and discrete entities in the Geography CAPS. Examples from the Grade 11 CAPS document will be provided to substantiate this finding.

The Grade 11 Geography CAPS document lists five main themes: 1) *geographical skills and techniques,* 2) *the atmosphere,* 3) *geomorphology,* 4) *development geography,* and 5) *resources and sustainability* [8].

The theme *geographical skills and techniques* deals with the subtopics of map skills, GIS, and topographical and aerial maps. The second theme, namely the *atmosphere*, deals with subtopics such as the earth's energy balance, global air circulation, Africa's weather and climate, and drought and desertification [8]. The theme *geomorphology* addresses topics such as mass movements and human responses, the topography associated with horizontal and inclined strata and massive igneous rocks, and slopes. The fourth theme, *development geography*, emphasises the concept of development and related issues, frameworks and challenges. In the last theme, namely *resources and sustainability*, reference is made to the use of resources, soil and soil erosion, and energy sources and management in South Africa [8]. Although these feature as key topics in the CAPS document, they are presented in a compartmentalised way. It is not made clear how these themes connect to one another. Ultimately, teachers teach according to this form of content representation in the CAPS, which contributes to fragmented understanding and learning among students.

It is evident that, in each of the themes mentioned above, reference is made to the environment, place (although primarily in terms of a physical location) and (sustainable) development, but not in an integrated fashion. Links between certain themes could have featured more explicitly in the CAPS in order to enhance teaching and learning. For example Africa's climate and weather could have been integrated with the earth's energy balance (the atmosphere), mass movements and human responses (geomorphology), development issues and challenges (development geography), and map skills (geographical skills and techniques). Morgan [9] asserts that *sustainability, environment* and *place* are the key integrated elements that lie at the core of the discipline of geography, and should therefore be treated as such. However, the lack of connection and interrelatedness is evident in the way that geographical themes have been outlined in the CAPS [8].

As mentioned earlier fragmented and mechanistic approaches to geographical teaching, learning and understanding, ultimately hinders the type of holistic, integrated and systemic understanding that is needed to develop a "sustainable, environmental and place consciousness" among students [1, 10]. Consequently, teachings and pedagogies of this nature not only deliver the type of student who perceives the world and its systems as disconnected, but they also disregard two of the core principles of Geography teaching, namely holism and integrated learning [11]. Ultimately, students end up studying "place" in terms only of location (coordinates on a map), the environment only in terms of its biophysical dimension, and (sustainable) development only in terms of economic growth. This subverts and undermines the goal of Geography Education, which is to enable students to think holistically and to see the connections between concepts, spatial patterns, people, nature and place.

The issue of fragmentation in Geography Education was also mentioned as a point of reference in a study conducted by Pretorius [2]. He investigated the composition of undergraduate Geography curricula in an attempt to reposition and strengthen the position of EfS (Education for Sustainability) in the Geography curriculum at the undergraduate level in South Africa. The study found that, even though Geography is presented in academia as an integrated science, this remains nothing more than a "theoretical ideal", since most undergraduate students are introduced to a fragmented discipline that lacks an integrative disciplinary narrative [2]. However, most studies which refer to the notion of fragmentation excluded from their discussion the role that education at school level can play. Therefore, this article attempts to address the issue of fragmentation from the level of school geography, as in my experience first-year students view geographical phenomena within an established "fragmented" frame of mind developed at school.

I concur with Pretorius [2] that Geography requires a reconfiguration of its main identity, away from existing binaries and towards more integration. This will remain a challenging task, as many South African geographers and educators either disregard integration or are completely unaware of the need for integration [2].

3.2 Observations of First-year BEd Students

Writing from my own position as a Geography Education lecturer, it has come to my attention that even though first-year BEd students do possess a satisfactory amount of knowledge about the notions of *(sustainable) development, environment and place*, they nevertheless find it challenging to make conceptual links between them and struggle to understand how the notions are interrelated and

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operate within a real-life, authentic system. For example, when they are asked: "How can the social environment in Khayelitsha (an informal settlement in the Western Cape, South Africa) develop sustainably over a period of 10 years without causing the other dimensions of the environment (economic, biophysical and political) to deteriorate?" they tend to struggle to unpack the question. There could be various reasons for this, such as students' lack of conceptual and procedural understanding,[4] or the inability to interpret, analyse and articulate their thoughts in a coherent way. However, when the question is ask differently, and the terms, "environment" and "sustainably" are excluded from the question – for example: "What should be done for the social dimension of Khayelitsha to develop substantially (having the least negative impact on the other dimensions) over the next 10 years?" – students are more prone to respond and engage.

This leaning among students continued even though most of the themes related to the questions as reflected in the course outline were already covered. The students struggle to synchronise the theoretical themes (such as settlements and population) with geographical skills (map work and GIS) in order to formulate a substantial answer. They do however, possess the necessary skills required to find South Africa, the Western Cape Province and Khayelitsha on a map, and also to perform basic map work calculations. In other words, students do have the technical knowledge and skills to find the physical location of a place. Yet they lack the relevant knowledge and reasoning skills to deal with notions such as "sustainable development" and how this relates to the social dimension of a place. In cases where students are asked to do an environmental impact assessment of a place, they are required to provide an in-depth analyses of quantitative and qualitative data. This implies that they would also have to understand and investigate the *sense of place* of the people living in Khayelitsha in this specific instance. This too is challenging for them, as *sense of place* is absent from the Geography CAPS document, although it is an integral concept of Geography and Geography Education. Perhaps this could be one possible reason for why students struggle in unpacking nuanced and integrated questions such as the one mentioned above.

The narrow and limited understanding of key concepts among first-year BEd students is also evident in their perceptions of the term *environment*. It was found that they still view the environment in terms of the natural environment only. The moment terms such as social, political or economic are added – for example, "political environment" – students tend to get confused. Although students are capable of making minimal connections to themes such as minerals, resources and tourism as stipulated in the CAPS, [8] they struggle to relate these to the term development and there understanding of the latter is primarily in terms of economic development.

As a lecturer, one has to bear in mind that this fragmented perspective among students did not develop in a vacuum and many factors contributed to this problem. As mentioned earlier, one obvious factor to consider is the representation of content and assessments in the Geography (CAPS) document (Grades 10 to 12). The CAPS has a direct influence on how teachers teach as well as on the development of students' thinking, learning and understanding throughout and after their school career.

The content in the CAPS was further analysed against a literature review on the purpose of Geography and Geography Education in order to determine whether it corresponds with the broader purpose of Geography and Geography Education (relevance).

3.3 The Purpose of Geography and Geography Education

In his book "*What is geography?*" Alistair Bonnett defines the discipline of geography within a wider set of economic, social and cultural processes. According to Bonnett, [12] "geography attempts to describe and explain the world and its peoples". He adds that geography is concerned with the relationship between humans and the world. According to Matthews and Herbert [13], geography as a discipline is rooted in three core concepts: *space, place* and *environment*. They argue that the "essence" of geography is the area where the three concepts overlap as "an integration of spatial variation over the Earth's surface with the distinctiveness of places and interactions between people and their environments" [13]. The authors further assert that the nexus where the three concepts overlap is indefinable and suggest that the term "landscape" comes closest to capturing its meaning. They state that the nexus of space, place and environment is unstable and has changed over time as academic geography developed. The authors identify five developmental phases: 1) exploration, 2) the establishment of the discipline, 3) the dominance of regional geography, 4) the emergence of physical and human geography, as well as systematic approaches, and 5) the current phases of divergent sub-disciplines in geography characterised by increasing specialisation and fragmentation [13]. This article is especially focused on the latter phase.

Starting with school Geography, Lambert [14] claims that there are three big ideas underpinning the subject: *place, space and scale*. From this it can be inferred that *place* and *space* are key concepts in both the academy

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and in school Geography. It is therefore argued that geography educators could revive these concepts through implementing a pedagogy of place. Lambert and Morgan [15] remind us that the responsibility for the quality of the educational experience in Geography lies mainly with school teachers. The authors state that this is because *they* – the teachers – are in a position to design and create appropriate curriculum and pedagogic experiences. It is *they* who use the subject resources to create productive teacher-learner relationships. Rawding [16] takes up this debate by emphasising the increased need for teachers to remain up to date with current developments and to engage intellectually with the fluid and complex conceptual territory of geography as a discipline. However, for Stradling [17] the need for geography educators to remain up to date is not that simple, as he claims that "the more contemporary the issue, the greater the problems for the [educator]". Based on the pivotal role that Geography teachers and educators (should) play, the researcher concurs with Butt and Collins, [18] who appealed to school and university geographers to engage seriously in dialogue, redefine school Geography and promote currency of knowledge.

It is at the intersection of academic and school Geography that the prominent role of the Geography educator and/or lecturer becomes most evident. It often becomes a daunting challenge for lecturers to operate at this interface and deal with issues of super-complexity which defy clear "proof" and do not provide definite "clear-cut" answers [14, 15]. Morgan [9] argues that, unlike any other non-humanities subject, Geography raises complex ethical and moral questions. Such questions are evident in the land reform issues that currently prevail in South Africa, as well as in the recent drought and fire catastrophes that hit the Western Cape province. Such phenomena are cognitively challenging as they inevitably call for new understandings of human-environment relationships that often do not resonate with many prevailing beliefs and world-views [19]. It is in the light of this complexity that O'Brien [20] calls for a new Geography or new "science" (as she refers to it) as a response to the challenges of the 21st century.

It is argued that for Geography to be relevant, in order to address the urgent challenges faced by society, a revolution is required in the system of education [21]. This would entail challenging underlying assumptions and beliefs in order to transform the system and also the way in which the system is perceived. O'Brien [20] further claims that environmental problems such as climate change are manifestations of modernity, symptoms of dominant patterns of development, outcomes of social relations, and products of short-sighted perspectives which are closely linked to beliefs, values and world-views [19, 20]. It therefore becomes important for the Geography educator to develop a type of "ethical knowledge" among students to tackle many "geo-ethical" issues (such as environmental decay, terrorism, conflict and poverty).

The researcher contends that this new geography and deeper understanding that O'Brien [20] advocates could be found in the reconceptualization of the field in terms of its intra-disciplinarity. The notion of place (a pedagogy of place) as a potential conceptual framework for advancing a new world-view in the field of Geography Education is therefore proposed. However, the community of geography teachers often overlook the intra-disciplinarity of their field and rather search for inter-subject collaboration outside of their discipline that relates to their area of specialisation. Although taking the latter route is not inappropriate or "wrong", it is argued here that a turn to Geography's intra-disciplinarity is much needed in the light of the current challenges. Pretorius [2] makes the point clearly: "Geography needs to come to grips with its own "intradisciplinarity" [first] for the discipline to be able to take its place in interdisciplinary collaborations with other disciplines/fields".

A turn to Geography's intra-disicplinarity would require a fresh understanding of its key concepts, such as *place*, which is considered as one of Geography's "big ideas" according to the 2009 manifesto of the Geographical Association (GA) [22] and the CAPS document [8, 23].

According to Hurry [11] holism and integrated learning should be the two core principles of Geography teaching. The researcher argues that these two principles could be understood from within the discipline itself. Using a concept such as "place" to demonstrate this is not far-fetched as the term encapsulates both the Physical and Humans Sciences as well as map work and GIS. The following section addresses the notions of fragmentation and integration before turning the discussion to the concept of place.

3.4 Fragmented Thinking and the Ideal of Integration

According to Skole, [23] global environmental crises have signalled a growing need for a fully integrated approach to human-environment interactions, thus presenting an appropriate opportunity for Geography to respond as an integrative discipline. Hurry [11] claims that geography practitioners must be encouraged to think about and teach their material in an integrated way. According to him, the holistic thinker is one who has an overview of his or her subject and does not see topics as isolated and discrete entities. He further emphasises that such holistic thinking must be nurtured in the Geography student, be-

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cause the subject of Geography is concerned with systems and processes. As he puts it: "one cannot fully understand the one component without a proper appreciation of the other" [11]. Although I concur with Hurry, I argue that authentic holistic thinking in Geography will only be possible once the divide between the four branches of school Geography (Physical Sciences, Human Sciences, Map work, GIS) is properly addressed.

Hawley [24] states that there is a dominant divide between human and physical geography in schools, even though the aim is to bolster integration. According to Matthews and Herbert [25], the two decades prior to 2004 witnessed significant debates among academic geographers regarding the nature of this gap and how it can be narrowed in profound ways that would unify geography as a discipline. However, the authors claim that this issue has been addressed very simplistically at school level, often by providing "applied problem-solving" tasks rather than highlighting the complexities of a holistic approach that would also take into account people's perspectives on the physical environment [26, 27]. These debates underlined the need for geography educators themselves to discover the possibilities and potential embedded in the discipline itself.

Furthermore, it is argued that if Geography is to survive, a new perspective is required on the implications of the discipline's own "intra-disciplinarity" [2] – "the presence of physical science and humanities in one discipline", as Evans and Randalls [28] put it. It is therefore important that opportunities for narrowing the gap between these two branches as a means to foster integration should be attended to first, before Geography can claim its rightful place in interdisciplinary collaborations [2].

3.5 Potential Avenues to Consider for Integration

3.5.1 Exploring Geography's Intra-disciplinary Nature

The notion of intra-disciplinarity can be closely linked to the concepts of intra-actionality and agential relationalism, as explored by Karen Barad [29]. The neologism "intra-action" underlines the mutual constitution of subject and object, that is, that they are only relationally or analytically distinct and do not exist as separate individual elements [29]. Barad further argues that scientific knowledge and reality in itself are not "built by things-in-themselves" or "things-behind-phenomena", but of "things-in-phenomena" [29]. Barad's agential realism the universe comprises phenomena, which are "the ontological inseparability of intra-acting agencies" [29]. This notion refers to a form of constructivism that is not relativist, but relationalist, that is, building on the idea of an intra-active interdependence between elements, that makes both parties contribute to the "construction" of the other.

In the case of Geography, this implies that educators should not treat the physical sciences or human sciences as separate from map work and GIS, but should in fact start to acknowledge the intra-active mutual dependency among these branches and realise that each one contributes equally to the construction of the other. Treat these branches as distinct from one another would result in reproducing segmented geographical pedagogies, theories and solutions to ever-changing environmental concerns. In fact, it would be an injustice to the discipline of geography. Realising the mutual constitution of the discipline – in other words, the intra-dependency among the different branches and treating the constituents equally at the level of pedagogy – could be a starting point for geography educators seeking an integrative pedagogy.

The following sub-section presents a discussion on how place-based pedagogies can offer a renewed perspective on geography education; the intra-actionality between place-based education and geography education will be demonstrated.

3.5.2 Utilising Place as a Key Concept in Geography Education

According to Argawal [30] the ambiguity of some geographical concepts often causes problems in the specification of a geo-ontology. However, although defining "place" remains a challenging task, a number of theoretical frameworks can be useful to clarify the term. For example, Gruenewald's [31] *multidisciplinary analysis* of the term "place", Creswell's [32] tripartite distinction of *place as area, location and sense of place*, and Ardoin's [33] and Resor's [34] *sense of place* could assist the geographer and Geography lecturer to expand their views on the concept of place. Elsewhere it has been argued that in order to practise a place-based pedagogy as a means to bridge geographical themes, it is imperative to understand the notion of "place" in broader terms [10,35,36].

The concept of place-based education was first articulated in the academic literature by education scholars such as Smith [37] and Gruenewald [31]. Hence, it is a fairly new educational response to promote integrated teaching and learning. These scholars relied primarily on two intellectual sources – Orr's [38] ecological education and Theobold's [39] and Theobold and Curtis's [40] community-oriented rural education. According to Israel [41], place-based education (PBE) calls for a thorough reorientation of pedagogic practice, challenging the isolation of schools and tertiary institutions from their social and ecological

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contexts, as well as the isolation of topics from one another. It is argued that the use of place as a starting point in teaching geography will enable students to understand the localness of environment (systems, problems, issues), even those aspects that transcend national boundaries [35,36].

Place-based education might help students to comprehend how the livelihoods of people living in rural areas depend on the land and could also serve as a basis for integrating indigenous cultural practices and philosophies such as *ubuntu* (humanness) into Geography education processes [36]. Through connecting with places, students could develop a greater awareness of how the local and global are intertwined [36].

If one applies a place-based approach to the example of Khayelitsha mentioned earlier, this would entail integrating the frameworks of Cresswell [32], Ardoin [33] and Gruenewald [31]. For example, students could study the exact location of Khayelitsha on a map – in absolute and relative terms (place as area – coordinates on a map) and connect the data gathered from the map work to physical and human geography. This could be done by asking key geographical questions such as: What does the location of Khayelitsha imply about the climate (Africa, South Africa, Western Cape climate and weather patterns) settlement and economic activities prominent in Khayelitsha? GIS and remote sensing could be use to provide more information on sanitation and hygiene facilities in Khayelitsha. Students could study the common environmental problems prevalent in the informal settlement and look at the effects they have on the human-nature relationship, climate and the economy.

Last, but not least, students will have to look at the sense of place of the inhabitants of Khayelitsha, in other words, the emotional and affective bonds that people have with the place. This means they will have to listen to the narratives of the people of Khayelitsha and investigate what exactly it is that makes them feel attached to the place; how they sustain the place and how the place sustains them; and how they connect to the physical features of the place (natural environment/the land) and to the community with whom they share the place. The affective and ethical dimensions (sense of place) are seldom theorised about or integrated with geographical content or coursework.

By applying this example, the robust relations between PBE and Geography become evident. For example, the out-of-the-classroom teaching and experiential learning of a place-based approach, as in the Khayelitsha example, is related to Geography's strong fieldwork component. Fieldwork in Geography is concerned with knowledge and skill acquisition, and with the purpose of "going and finding out" about the place visited [41]. In this sense, the experience and expertise that Geography educators have developed in fieldwork can enable place-based programmes to connect more fully and effectively with the places in question. The next sub-section will elaborate on how PBE and GE share certain commonalities which can mutually contribute to the theoretical "gaps" in each field respectively.

3.6 The Intra-actionality between Place-based Education and Geography Education

The conflict in teaching styles among lecturers is becoming more prominent in contemporary geography teaching. Place-based approaches in Geography promise a more comprehensive avenue towards engaging pedagogy and content. This is based on the fact that place is considered a key and integral part of Geography [8,22].

From a South African perspective, the researcher concurs with Israel [41] who claims that, despite clear affinities of topic and purpose, geography educators have not adopted the pedagogic framework of PBE, nor contributed to scholarship in this field. Israel [41] further argues that PBE can enrich the theory and practice of Geography Education (GE), providing both an articulation of the social significance of learning about place as well as practical ways to make that significance a reality. It is argued that GE could also contribute significantly to the field of PBE in expanding its theoretical foundations. In this sense, both PBE and GE are mutually supportive strands. Equally, geography educators can enrich place-based education theory and practice by applying Geography's expertise in understanding and analysing how places work. This dual support can be enhanced by including Gruenewald's [31] multidisciplinary analysis, Cresswell's [32] distinctions regarding the concept "place" and Ardoin's [33] sense of place frameworks.

Furthermore, Israel [41] asserts that the interconnections between nature and society, the importance of scale and spatial dynamics, and the ways places are constructed and modified through cultural processes are all areas in which geographers have produced rich insights, yet these aspects of place are often inadequately addressed in theories on place and PBE. Conversely, PBE uses field-based experiences to enable students to situate themselves as members of social-ecological communities and to cultivate a sense of ethical responsibility. Thus, the use of field experiences in PBE provides a framework from which Geography educators can connect the practice of field education with the growing interest in "teaching geography for social transformation" [42] by connecting field experiences with ethical purposes [40]. This once again emphasises the intra-action-

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ality among PBE and GE. Conceiving of the two fields in this way not only offers new pedagogical and conceptual pathways, but also aims to 1) overcome the compartmentalisation of the four branches of school Geography, and 2) transcend the dichotomy between PBE and GE.

Based on the above arguments, one can infer that PBE employs an explicitly geographical take on social concerns (environmental social justice), aiming to transform both students and the places they inhabit through pedagogic engagement with places. Israel [41] asserts that, in this way, PBE provides a vision of how approaches common in GE can respond directly to the ethical and political concerns of critical Human Geography. In the same way, Geography Education's field-based inquiry into how places work can expand the theoretical and practical frameworks of PBE and contribute to its pedagogic potential.

4. Implications

It is clear that Geography's synthesising and spatial approaches could provide a uniquely valuable perspective for the study of a place and a conceptual depth often lacking in PBE. It is therefore up to the Geography teaching community as a whole to return to Geography's intra-disciplinarity, that is, utilising its key concepts such as place.

However, in order to realise the potential of a place-based approach in Geography and GE implies that Geography educators should expand their understanding of "place" beyond its technical dimension by embracing the multidimensionality of the concept, as proposed by Gruenewald [31]. Furthermore, the three distinctions of place identified by Cresswell [32], in conjunction with Ardoin's [33] and Resor's [34] sense of place frameworks, should be integrated when theoretical topics, map work skills and GIS are taught. This implies that these theories should be seriously considered in Geography programmes and curriculum designs, and more so in pedagogical frameworks – both at school and tertiary level.

Therefore, both the place-based educator and the Geography educator should collaborate and exchange valuable knowledge by reflecting on the potentiality of the existing intra-actions which transcend the "flawed" dichotomy between the two. This suggests that Geography educators and education researchers who seek to respond to pressing social and ecological concerns should develop connections, both in theory and in practice, with place-based educators and place-based education scholarship. In this sense, the interrelatedness of geographical phenomena will gain renewed emphasis.

Israel [41] further claims that the Geography educator can use the local scale to point out the degree of heterogeneity within a community, for example, by highlighting differences between neighbourhoods within a town, or to the discourses that marginalise or stigmatise certain areas (such as slums). Within PBE, the educator can counter the notion that place be studied as static, homogeneous and isolated by drawing attention to the ways in which a place is situated within broader-scale political, cultural or ecological landscapes, and also by studying the spatial distribution of resources, communities and activities on the local scale. This is also a useful example to consider when teaching those "segmented" themes in Grade 11 (as mentioned earlier).

Adopting a geographically informed place-based pedagogy would require of educators to pay careful attention to the ways in which the places involved are represented in discourses and are experienced by students in field-based activities. In that sense, the students' sense of place becomes an important aspect to take into account. This might result in educators seeking out the stories of minority groups within the community, or visiting marginalised neighbourhoods in the local area, rather than limiting the focus to majority representations of the place [42].

5. Concluding Thoughts

This paper has argued that a (re)turn to Geography's intra-disciplinarity by means of a place-based approach offers a potentially valuable avenue for transitioning from fragmented to integrated teaching and learning in Geography and Geography Education. It has been demonstrated that profound interactional connections between concepts such as place, space and environment may be identified and that these connections can enhance pedagogy if geography educators be aware of their potential. The researcher contends that place-based pedagogies present an opportunity for Geography educators to expand their expertise beyond the spatial and scalar characteristics of the discipline in order to foster integration and thus support them to adequately prepare student teachers. Establishing such connections with place-based pedagogies will be a crucial step in bringing about "what geography ought to be" - a source of pedagogical inspiration and a force in creating a better world [43]. This article will be followed up with another article where the focus will be on a more practical application, as this one has served only as an introduction to the potential of a place-based approach for exploring the intra-connections in geography.

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ARTICLE

Analysis of Climate Change in the Area of Vojvodina-Republic of Serbia and Possible Consequences

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ABSTRACT

Climate change conditions a wide range of impacts such as the impact on weather, but also on ecosystems and biodiversity, agriculture and forestry, human health, hydrological regime and energy. In addition to global warming, local factors affecting climate change are being considered. Presentation and analysis of the situation was carried out using geoinformation technologies (radar recording, remote detection, digital terrain modeling, cartographic visualization and geostatistics). This paper describes methods and use of statistical indicators such as LST, NDVI and linear correlations from which it can be concluded that accelerated construction and global warming had an impact on climate change in period from 1987 to 2018 in the area of Vojvodina – Republic of Serbia. Also, using the global SRTM DEM, it is shown how the temperature behaves based on altitude change. Conclusions and possible consequences in nature and society were derived.

1. Introduction

The current warming trend is of particular significance because most of it is extremely likely (greater than 95 percent probability) to be the result of human activity since the mid 20th century and proceeding at a rate that is unprecedented over decades to millennia.

The world is undergoing the largest wave of urban growth in history. At present, more than half of the world's population is living in urban areas such as towns and cities, and it is expected that by 2030 this number will increase to about 5 billion (UNFPA) [16]. There are 7,163,034 inhabitants in Serbia, of which 2,914,990 or 40.5% of the population live outside of urban settlements, and this number is constantly falling due to the transition from rural areas to urban areas. An increase in number of people moving from rural areas to urban areas has further influenced the climate change of major cities in Serbia.

Novi Sad ranks 2nd in terms of population and is the most urbanized city of Serbia with 341,625 inhabitants of which 277,522 live in urban areas. It has a relative high population density with 486 persons per sq km. This may

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be attributed to the fact that this city will be the European Capital of Culture in 2021, which will be the first time that this prestigious title bears a city from the country that is a candidate for EU membership. In addition to this, Novi Sad is a rapidly growing city and is also famous as a tourism destination among the masses. Therefore, as the industry and tourism sectors grow, the growth of service sector also accelerates, accentuating population growth. To accommodate this growing population, urban areas will further increase thus taking a toll on the natural resources. The study presented here gives an insight into the changing vegetation and temperature patterns of city Novi Sad and its surrounding areas due to increase in urbanization.

Estimates based on climate modeling, according to moderate scenarios, indicate that the annual temperature in Serbia will increase by 2.6 degrees Celsius by the end of the century. The heating will not be even during the year. The temperature of summer will increase by 3.5 degrees Celsius, autumn by 2.2, winter by 2.3, and spring by 2.5 [12].

NDVI is considered as an excellent indicator of vegetation density and is the most commonly used vegetation index. NDVI represents useful tool which can amalgamate vegetation, ecosystem, climate and environment and perform studies at large spatial and temporal scales [11].

The thermal infrared (TIR) band on the Landsat satellites is useful for calculating the LST. LST is defined as the interface temperature between the Earth's surface and its closest atmosphere, and therefore is a key variable for understanding the interaction between the earth and the atmosphere [16]. The correlation between the LST and vegetation indexes, such as NDVI has been documented. Mallick et al. (2008) examined the relationship between NDVI and LST using Landsat data and found strong relationship between these two variables.

In the present study, NDVI has been used to derive LST [19]. Also, using statistical calculations, a correlation between the NDVI index and the LST is determined, and in which linear relationship the two values are interrelated (regression). Based on this, it is shown how altitude change using SRTM DEM and construction expantion influences temperature change.

2. Study Area and Data Used

Novi Sad is located at 45° 20’ 00” N, 19° 51’ 00” E, in the central part of the Autonomous Province of Vojvodina, in the north of Serbia, at the border of Backa and Srem (Figure 1). The city covers an area of 702.7 square kilometers, at an altitude of 80 meters. According to the final results of the population census in 2011, there were 341,625 inhabitants in the administrative territory of the city of Novi Sad, while 277,522 inhabitants live in the urban area of the city of Novi Sad. On the left bank of the Danube there is a plain part of the town (Backa), while the hilly part of the city (Srem) is located on the right bank, on the slopes of Fruška Gora.

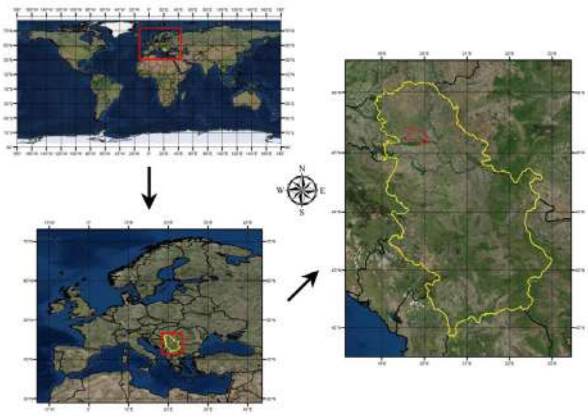

Figure 1. Location map of municipality of Novi Sad

Two Landsat images have been used for this study. The detail of the data used is given in Table 1.

Table 1. Specifications of Landsat data used in the study

Satellite/ Sensor	Acquisition Date(s)	Bands used	Spectral Wavelength (µm)	Spatial Resolution (m)
Landsat-5/ TM	25 Aug. 1987	Red (B3)	0.63-0.69	30
		Near-infrared (B4)	0.76-0.92	30
		Thermal infrared (B6)	10.40-12.50	120
Landsat-8/ OLI-TIRS	30 Aug. 2018	Red (B4)	0.64-0.67	30
		Near-infrared (B5)	0.95-088	30
		Thermal infrared 1 (B10)	10.60-11.19	100[1]
		Thermal infrared 2 (B11)	11.50-12.51	100[1]

3. Methodology

[1] TIR/TIRS bands are acquired at 120/100 m resolutions, but are resampled to 30 m in delivered data product

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3.1 LST Determination from Remote Sensing Images

To obtain LST from satellite sensors based on TIR measurements, radiometric calibration, emissivity and atmospheric corrections are required [8].

The Landsat OLI-TIRS had two bands - band 10 and 11 - but only band 10 was used here. Therefore, this study uses single-window based algorithm for NDVI to obtain land surface emissivity (LSE). From the various approaches given in the literature [19] [20], modification of the NDVI Thresholds Method (NDVI THM) [20] is used here. The following steps are followed to obtain LST from thermal images and NDVI images.

3.1 1 Calculation of Radiance Images

The raw digital number (DN) values of TM have been converted to radiance using the formula given by Chander et al., (2009):

$$L^* = \frac{(L_{max} - L_{min})DN + L_{min}}{DN_{max}} \quad (1)$$

where L^* is the spectral radiance received at the sensor; L_{min} and L_{max} are the minimum and the maximum spectral radiance for the sensor respectively; DN_{max} is the maximum DN. For TIRS, the following formula is used:

$$L^* = M_L \times DN + A_L \quad (2)$$

where *ML* is band specific multiplicative rescaling factor and *AL* is the band specific additive rescaling factor from the metadata.

3.1.2 Calculation of Radiant Temperature

Radiance images derived from thermal bands were used to calculate the radiant temperature using the formula [2]:

$$T_r = \frac{K2}{\ln\left(\frac{K1}{L^*} + 1\right)} \quad (3)$$

where *Tr* = radiant temperature (in Kelvin); *K1* and *K2* = pre-launched calibration constants 1 and 2 respectively (W/ (m2 sr μm)); *L** = spectral radiance.

3.2 Creation of NDVI Images

NDVI is first conceived by Rouse et al. (1973) and it is based on the absorption of light by vegetation in the red band and its reflectance in near-infrared band [4]. The value of NDVI ranges from -1 to +1 where -1 represents pixels having no vegetation and +1 pixels with dense vegetation. Values greater than 0.6 indicate the presence of thick green vegetation. As the values are closer to 1, the vegetation is denser. The range of values from 0.2 to 0.5 corresponds to low vegetation. Areas without vegetation have values close to zero, while negative values correspond to desert areas, water, clouds, snow covered areas, etc. NDVI can be expressed as [18]:

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (4)$$

where, NIR is the reflectance of near infrared band and R is the reflectance of red band.

3.3 Calculation of Emissivity

The emissivity of surface varies with vegetation, soil moisture, roughness and viewing angles. Three major methods are recommended in literature for LSE estimation for LST inversion [3]:

(1) classification- based emissivity method (CBEM),

(2) NDVI- based emissivity method (NBEM) and

(3) day/night temperature- independent spectral indices-based method [22].

NDVI was classified in three classes:

(1) bare soil: NDVI < 0.2, (b.),

(2) mixture of bare soil and vegetation: 0.2 ≤ NDVI ≤ 0.5 and (C.),

(3) fully vegetated: NDVI > 0.5.

LSE for each of these classes is estimated using the following equation [10] [22]:

$$\varepsilon_i = \begin{cases} a_i \rho_{red} + b_i & NDVI < 0.2 \\ \varepsilon_{v,i} P_v + \varepsilon_{s,i}(1 - P_v) + C_i & 0.2 \le NDVI \le 0.5 \\ \varepsilon_{v,i} + C_i & NDVI > 0.5 \end{cases} \quad (5)$$

Where, ρred is the reflectance of red band, Pv is the fraction of vegetation, εs and εv is the emissivity of soil and vegetation and ai, bi, Ci are the essential coefficients which are discussed in Yu et al. (2014).

Sobrino *et al*., (2004) considered 49 soil spectra included in the ASTER spectral library and obtained the following expression for deriving LSE from pixels having proportion of both soil and vegetation:

$$\varepsilon = 0.004 p_v + 0.986 \quad (6)$$

where pv - vegetation proportion and can be derived from NDVI image according to the equation given by Carlson and Ripley, (1997):

$$p_v = \left[\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right]^2 \quad (7)$$

where $NDVI_{max}$ = 0.5 and $NDVI_{min}$ = 0.2. The values 0.5 and 0.2 are used for scenes which have the presence of bare soil and vegetation respectively. It has been reported that this equation is the most suitable if there is a presence of bare soil and vegetation in a pixel, which is the case in the study area.

3.4 Calculation of LST

LST refers to the temperature of the surface layer of the soil. It differs from air temperature (temperature obtained within the weather report). LST depends on the albedo (the measure of the reflection of the sun's radiation from the surface of the Earth), the vegetation cover and the humidity of the soil. The outputs derived from Tr and ε have been then used as inputs to calculate the LST using the following formula [21]:

$$LST = \frac{T_r}{1+\left(\frac{\lambda T_r}{\rho}\right)\ln\varepsilon} \quad (8)$$

where λ = central wavelength (in μm) of the Landsat thermal band; $\rho = 1.438 * 10^{-2m}$ K.

The NDVI and LST images thus derived have been used to study the spatio-temporal pattern.

3.5 Statistical Analysis Methods

Correlation represents the interconnection between different phenomena represented by values of two variables. Linear correlation coefficient, as a relative measure, takes values from -1 to +1. If it takes positive values, the correlation between phenomena is either direct or positive (both phenomena show dichotomous variations). In the case where the correlation coefficient <0, the relationship is inverse or negative (when one phenomenon increases the other decreases, and vice versa). If there is a functional connection between the observed phenomena (all the empirical points are right on the right line), we are talking about perfect correlation. Then the coefficient of correlation takes the value -1 (if the connection is inverse) or +1 (if the connection is direct). When correlation coefficient in absolute value is closer to 1, the stronger is the correlation between the phenomena. On the contrary, the closer the linear connection is to zero the weaker is connection.

On the basis of the large number of samples examined, we cite a "rough" division of correlation coefficient values:

(1) >0.70 is considered a strong connection,

(2) 0.30-0.69 is considered to be a central connection,

(3) <0.30 no linear connection (does not exclude the existence of a nonlinear form of connection).

4. Results and discussion

Analysis of the results obtained requires a certain experience in the field of processing and interpretation of satellite images. The analysis represents a step between the processing of the image and a complete understanding of the results obtained and it makes it an instrumental in the complete process. The methods of analysis were visual and statistical.

The analysis itself begins with getting to know the target area, which in this case is the area of the municipality of Novi Sad. For analysis in this article satellite images were taken from August 25, 1987 (Figure 2) and from August 30, 2018 (Figure 3). The first step is a visual analysis of two images displayed in the true color combination of colors, in order to represent changes in Novi Sad.

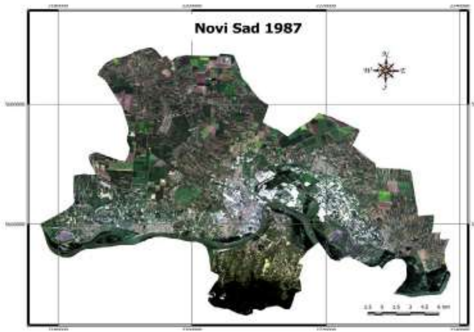

Figure 2. Display of the image from 1987 in the true color combination

Figure 3. Display of the image from 2018 in the true color combination

From the shown, it can be seen an increase in the construction in the western part of the city of Novi Sad towards Futog and the northern part of the city of Novi Sad, ie the settlement of Klisa, as well as the expansion of the neighboring settlement Rumenka. The city was also built in other areas, but the changes in these areas are the most obvious, thus pointing to potential characteristic results after the application of certain processing methods.

The next step is a confirmation of previously observed conclusions through formal analysis. First, the temperature values at the Earth's surface were calculated, for both data sets, using the LST index according to the above formulas. The obtained results are shown in Figure 4 and Figure 5.

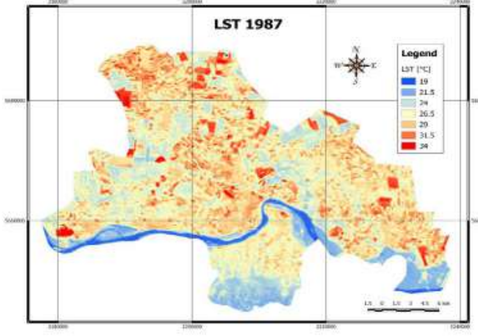

Figure 4. LST index for 1987 image

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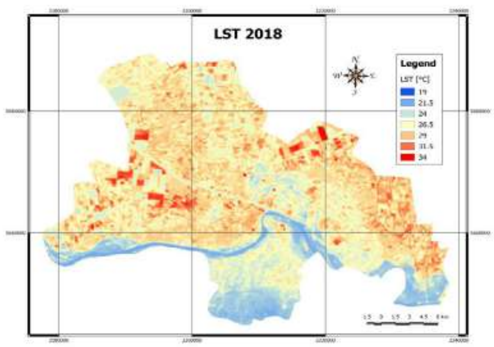

Figure 5. LST index for 2018 image

From the previous two images (satellite images from 2018) it can be seen the increase in the temperature of the surrounding agricultural land. Further, the minimum, maximum and mean temperature values in this area are analyzed, as well as the land in the western and northern part of the city of Novi Sad, where in this period of 31 years there has been intensive construction and expansion of the city. By inspecting the obtained numerical data (Table 2), the conclusion was made that in the period of 31 years the average temperature increased by 0.14 degrees. At the maximum value, it can be seen that the temperature in this period decreased by 0.59 degrees. The most interesting data is the one obtained for the minimum temperature, from which can be seen that the minimum surface temperature of the earth has increased by 1.99 degrees Celsius.

Table 2. The table of extreme and mean values of the LST index

Acquisition Date(s)	Min	Max	Mean
25 Aug. 1987	19.29	35.67	26.81
30 aug 2018	21.28	35.08	26.95

In order to better understand the obtained results, for the 500 arbitrarily selected points (which are correctly distributed in this test area) on which the temperature values were read, the histograms for both analyzed periods were formed (Figure 6 and Figure 7).

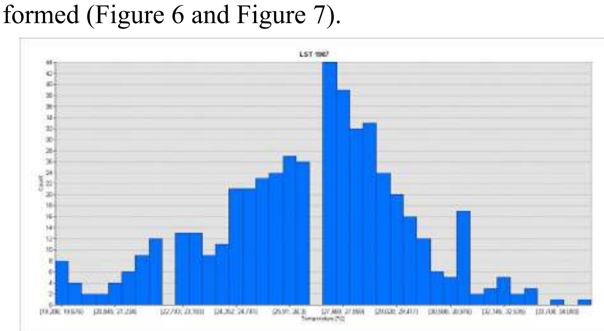

Figure 6. Histogram value for LST index for 1987 image

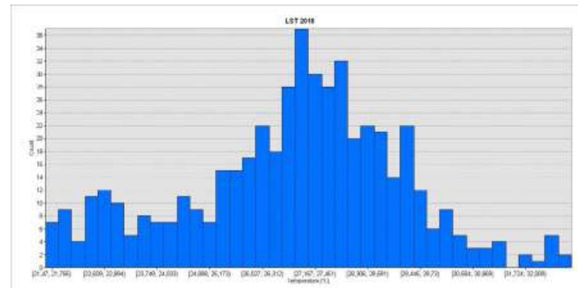

Figure 7. Histogram value for LST index for 2018 image

What clearly can be seen from above presented histograms is a much higher number of peaks with higher temperatures for image from 2018 than for the one from 1987. However, it can be stated with certainty that in this area, during the period of 31 years, there has been land warming, which is due to various factors such as global warming, urbanization and construction, etc.

High temperature areas also typically have lower NDVI values. This aspect has also been corroborated from the analysis of the relationship between LST and NDVI. There is an obvious correlation between NDVI and LST from the visual interpretation of NDVI and LST. In LST figures, the LST values of non-vegetated areas (built, infertile, dried riverbeds) are greater than those obtained for areas related to water bodies and vegetation, including agricultural land (Figure 4 and Figure 5). Values are opposite to NDVI images (Figure 8 and Figure 9). In order to study the variance of NDVI and LST, the pixel values of NDVI and LST that were derived show that LST peaks are usually in areas in which buildings are located, while the basins are mainly where water bodies and vegetation are located. NDVI peaks occur in vegetation areas, including agricultural land. So, NDVI and LST show an apparent negative correlation. In other words, the NDVI values are low (or even negative) where LST is high and vice versa. This is characteristic for both analyzed periods.

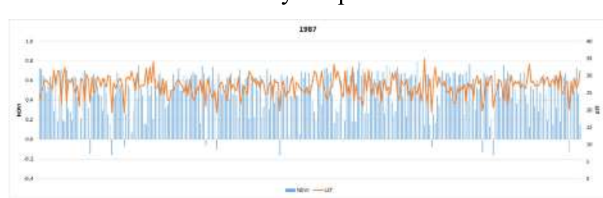

Figure 8. Correlation curves of NDVI and LST images of the 1987 year

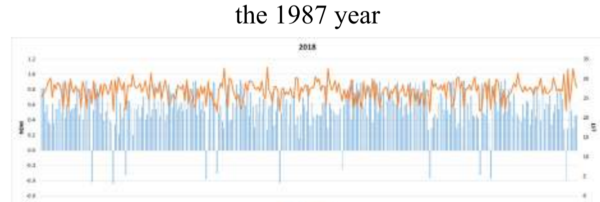

Figure 9. Correlation curves of NDVI and LST images of the 2018 year

In order to prove how the urbanization and expansion of the city, ie, the construction of new buildings has an effect on the temperature increase, as well as to examine whether and how accurately the newly built objects can be detected on the basis of soil temperature changes, the following analysis was made. First, the temperature difference from 2018 and 1987 was calculated, and then only the values with a difference greater than 3 degrees Celsius for the given area were shown. The result is shown on the following chart (Figure 10).

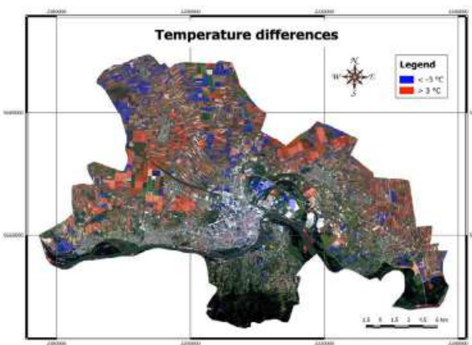

Figure 10. Difference temperature greater than 3 degrees Celsius

From the following picture (Figure 11) we can clearly see that the temperature at which the object was built has increased. As temperature of objects are more in relation to the soil temperatures, it comes to the conclusion that all the places where the new buildings were built can be clearly detected.

Figure 11. Detection of built objects

However, the problem occurs in places where there has been a change in the use of agricultural land. The problem case is shown in the following figure (Figure 12).

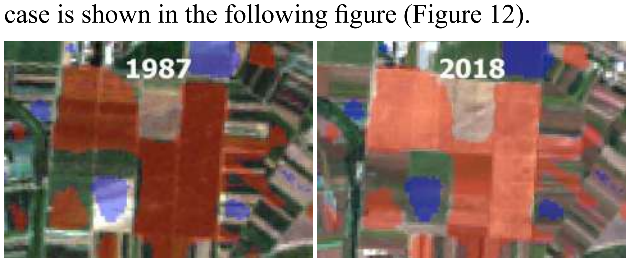

Figure 12. Error in the detection of built objects

Here it can be seen that on image from 2018 the area is covered with green vegetation, which is not the case in the 1987 image. Due to this fact, various soil temperatures occur, i.e. The land without vegetation is heated more and vice versa. Therefore, in all places where there has been a change in the use of agricultural land, a significant change in temperature will occur, and such places will be detected. Precisely because of everything previously explaned, this method for detecting built objects can not be considered reliable.

As the municipality of Novi Sad has mostly plain area, which is largely represented, and part of Fruska Gora, which has a much higher altitude than the surrounding area, the question is how the altitude change affects the temperature of the land.

By exemening next graph (Figure 13), which was formed on the basis of the previously created 300-point test model and for which the heights of the SRTM DEM are read, with the rise in height, considerably fewer oscillations in temperature variations appear. Thus, the temperature difference values for the plain part range from -10 to +9, and as the height rises, this interval decreases to 2 degrees. It should also be taken into account that the Fruska Gora National Park is a special nature reserve and that construction is not permitted in that part. Therefore, due to the fact that there is no change in the use of land in that part, there are no significant changes in temperature.

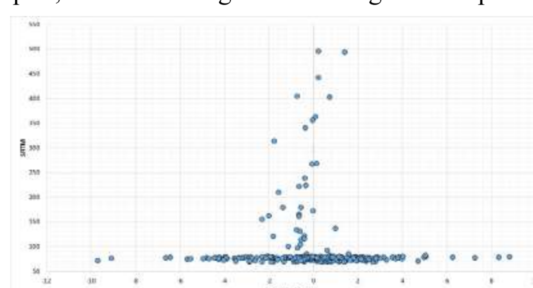

Figure 13. Changing temperature depending on height

Further analysis refers to temperature analysis for 10 characteristic locations. The coordinates of these points are given in Table 3. The spatial distribution of these points is shown in Figure 14.

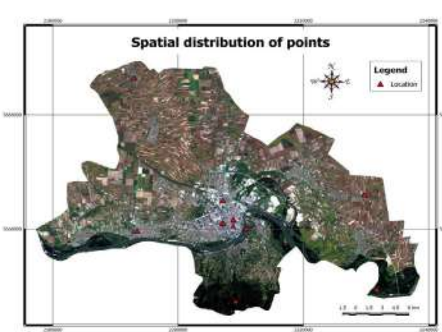

Figure 14. Spatial distribution of point

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It can be seen that data are collected from points located on different land use/land cover classes, such as built areas, vegetation areas, water bodies, reefs/open areas, for better representation.

Table 3. Test model and coordinate values and temperatures on them

Name	Latitude	Longitude	DEM	LST 1987	LST 2018	LST 2018 - 1987
Dunav	45°14'40.70"	19°51'38.10"	70.0	19.2861	21.7918	2.5058
Fruška Gora	45°09'47.58"	19°50'43.90"	416.0	21.9456	22.2635	0.3179
Stadium	45°14'48.27"	19°50'32.37"	74.0	29.6049	28.2021	-1.4028
Park	45°15'01.53"	19°49'37.28"	78.0	25.8325	25.5115	-0.3210
BIG	45°16'31.61"	19°49'37.79"	77.0	27.1030	32.1886	5.0856
Theater	45°15'15.72"	19°50'32.59"	82.0	30.8398	30.9707	0.1309
Futog	45°14'29.26"	19°42'16.38"	80.0	28.3600	28.6678	0.3078
Stepanovićevo	45°24'40.61"	19°41'58.90"	79.0	27.5229	27.2127	-0.3102
Field	45°16'53.56"	20°01'46.42"	77.0	32.4672	31.9203	-0.5469
Coast of the Dunav	45°10'36.70"	20°02'53.42"	75.0	21.9455	23.8695	1.9239

To better understand soil temperature variation, a graph is given (Figure 15), for which for each characteristic location the obtained LST temperature values for both analyzed periods in the form of bar graphs are displayed. From the table and from the graph shown, it can clearly be seen that the greatest increase in temperature is at the site of the BIG shopping center, which occupies a large area and which has a large parking lot, and as there were no objects in that place in 1987, this result is very logical. At locations representing arable land and parks, we even see a decrease in the temperature for small values. It is also interesting to note that the value of the Danube and narrow band along the river has increased.

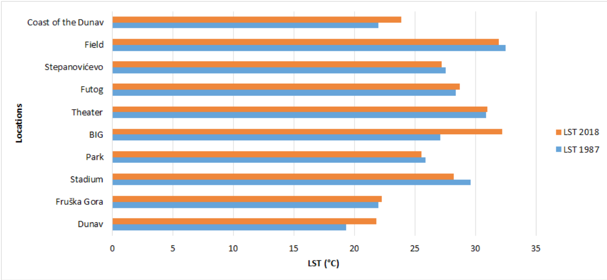

Figure 15. Comparative analysis of temperature values for each point

Healthy vegetation represents power and greenery that can be directly linked to NDVI, as well as conditioning the crops. The high values of NDVI are shown as crops, orchards and forests as a result of a high level of green biomass, while low NDVI values represent a bare ground and urban area. The scatter graph was generated for both periods, for a previously created 300-point test model for which the results of the obtained NDVI and LST indexes were read (Figure 16 and Figure 17). Figure 16 shows the dependence between LST and NDVI index for 1987, and on Figure 17 is the dependence between LST and NDVI index for 2018.

As previously stated, the values of the R^2 coefficient range from 0 to 1 and tell us how many variables (NDBI, LST) are dependent on one another. If $R^2 = 0$ there is no linear connection and the variables are independent. The $R^2 \sim 1$ linear bond between the variables is stronger. Variables in linear equations are: Y - LST, X - NDVI, R^2 - determination coefficient.

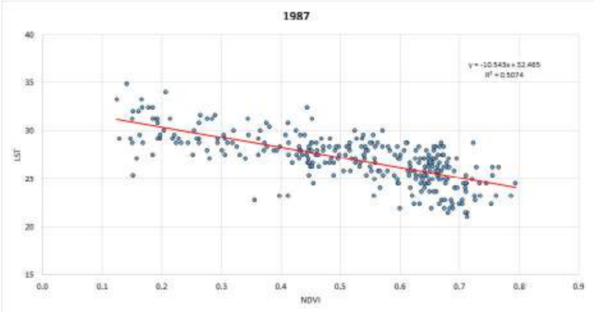

Figure 16. Scatter plot between LST and NDVI for 1987

As we see on the first chart for 1987, LST has a negative correlation with NDVI ($R^2 = 0.51$). for agricultural land. This is further taken from labor and changes slightly: It means an area that has more vegetation is having low temperature because the available energy is parting more towards the evapotranspiration process, so that LST will be lesser as compared to the low vegetation area. Scanty vegetation also has higher LST due to low NDVI value.

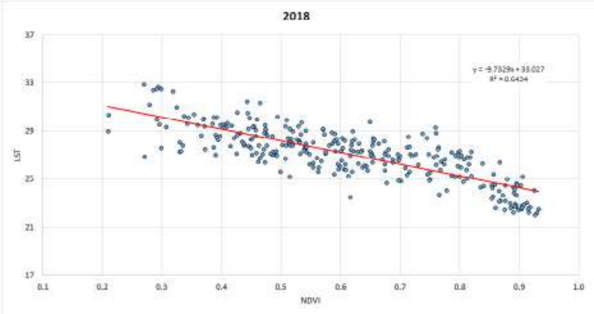

Figure 17. Scatter plot between LST and NDVI for 2018

From the second graph from the data obtained for 2018 we see that LST as in the previous case has a negative correlation with NDVI ($R^2 = 0.64$).

5. Conclusion

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First, it is important to clarify that climate change differs from global warming. This is a mistake made by many, especially the public. Although many aspects of climate change relate to heating problems, this concept also covers other complex climatic conditions. Regardless of their nature, the role of human activities in this climate change is certainly a matter of great concern. For example, anthropogenic global warming is simply an expression that is used for global warming caused by human activity.

In recent decades, climate change has become a major theme in the world. Over the past century, global temperatures have increased by 0.8 °C, since the CO2 concentration in the atmosphere has increased from 280 to 370 ppm: it is expected to double to 2100, followed by a temperature rise of 1.1-5.4 °C above the 1900 level (IPCC, 2007).

In fact, most recorded global warming has occurred over the past four decades, and 2016 and 2017 have been certified as the hottest years of record. If this continues to increase, as is expected in urban areas, in particular, we should testify to serious cases of urban overheating scenarios.

This also causes changes in existing weather patterns, including increased frequency and size of drought, floods and other extreme weather conditions [5] [6]. These changes are mainly attributed to the increased human exploitation of natural resources, especially fossil fuels (the release of greenhouse gases into the atmosphere), but also to industrialization, forest degradation and urbanization affecting the nature of landscapes (IPCC, 2007). We defined urbanization as a substitute for nature by culture [14].

Climate change is being perceived as the greatest challenge of this era. Anthropogenic (ie Human) activities were the main factor in global warming, which led to a change in weather patterns, which in turn exacerbated socio-cultural issues such as hunger, drought and the rise in sea levels that led to mass migration and demographic displacement.

In the context of the urban environment, "urban" includes not only the city center, but also the surrounding suburbs, urban greenery, industrial areas and rural-urban edges [13]. This is a growing and inevitable phenomenon: in 1960, 60% of the world's population lived in rural or semi-rural areas in villages and small towns, but by 2030 it is projected that 60% of the world's population will live in urban areas. Areas, and the quality of life for future generations will inevitably be associated with the urban environment [13].

It is also noticeable that the impact of climate change on different parameters can be increased in urban centers other than natural areas, possibly due to the creation of urban thermal islands, making most of the urban areas warmer than the surrounding areas.

This study analyzes soil temperature change in the last three decades in the municipality of Novi Sad. The integrated remote-access approach has been successfully applied to determine the NDVI and LST changes using satellite images. Reduction of vegetation, spreading of the urban area ie. construction of new buildings, changes in land use patterns and other parameters were accompanied by the increase in the minimum and maximum LST of the surfaces. It was also attempted to identify newly constructed objects using a temperature difference, since it is assumed that temperatures would increase in such places. It turned out that this method is able to identify such sites, but that it is not reliable due to the fact that other land that has changed the way agricultural land is identified. After that, the temperature variation was analyzed depending on the alteration of the height difference. Then, using the regression analysis, it was attempted to determine the dependence between the NDVI and LST values. It turned out that there is some dependence, but there is no strong connection between these two values. All these changes indicate the rapid urbanization of the city of Novi Sad and the surrounding areas. This kind of study is therefore used to monitor urban expansion and other vegetation related phenomena.

In recent years, the application of heat data has been significantly increased in all types of Earth observation based on the application of research such as water management in agriculture, water resources management, crop evapotranspiration assessment, energy balance studies, climate change, hydrological cycle, vegetation monitoring, urban climate and ecological studies, etc. [7] [17]. LST quickly varies with space and time due to the heterogeneity of surface parameters such as soil, water, vegetation, and therefore measurements on the ground are not reliable in wide areas. Remote reading can help us measure LST for a whole sphere with fine spatial and temporal resolution, not with exact observations.

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ARTICLE

Waptia-like Euarthropods from Burgess - Shale - type Biotas in the Early Cambrian of Eastern Yunnan, China

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ABSTRACT

Waptia-like euarthropods existed for rather a long time in the Early Cambrian of eastern Yunnan; well preserved representatives come mainly from three Burgess Shale-type biotas: Chengjiang, Xiaoshiba and Guanshan. Here, we introduce a newly-discovered bivalved euarthropod from the Guanshan biota, the specific identity of which cannot be confirmed due to the absence of soft parts and poor preservation of the specimen, but its general morphology allows it be attributed to *Waptia*. Two representatives from the Chengjiang and Xiaoshiba biotas are also reconsidered: the preservation mode and length of specimens of *Clypecaris pteroidea* are variable; *Clypecaris serrate* has limbs beneath the carapace, which can number up to at least 4 pairs. The fossil sections bearing *Waptia*-like euarthropods occur over a wide area around Dianchi Lake.

1. Introduction

More than 100 years have passed since the first *Waptia*-like euarthropod was discovered. Hitherto, in addition to the type species, *Waptia fieldensis* Walcott, 1912 [1] from the Burgess Shale, Canada, representatives from Early or Middle Cambrian deposits in other areas have also been reported, e.g. in Utah, U.S.A. [2] and Sirius Passet in Greenland [3]. In recent years, based on new specimens and new technology, the neuroanatomy, reproductive strategies, feeding mode and affinity of *Waptia fieldensis* have also been described and discussed [4-9]. All these works have helped to reveal the original appearance of this bivalved euarthropod. There are also occurrences of *Waptia*-like euarthropods in Early Cambrian localities in eastern Yunnan, especially in the three classic Burgess Shale-type biotas: Chengjiang, Xiaoshiba and Guanshan. Here, we report a species of *Waptia* from the Guanshan biota, reconsider two representatives from Chengjiang and Xiaoshiba, and briefly discuss the temporal and spatial distribution of *Waptia*-like euarthropods in the Early Cambrian of eastern Yunnan.

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2. Materials and Methods

2.1 Materials and Methods

The total of three specimens discussed here come from three different biotas: the Chengjiang biota (YN-JS-500), the Xiaoshiba biota (YN-GS-001) and the Guanshan biota (YN-GLF-831). The last two specimens were prepared using a fine needle under a binocular microscope, revealing parts covered by the matrix. Digital photographs were taken using a Canon EOS 5D MkIII camera and 50 mm macro lens, dry under cross-polarized light and processed in Adobe Photoshop CS 4. Line drawings of all specimens were made using Adobe Illustrator CS 3. Terminology follows Vannier et al. [9], Straufeld [7] and Yang et al. [10].

2.2 Repository and Institutional Abbreviation

The specimens are housed at the School of Earth Sciences and Resources, China University of Geosciences (Beijing) (CUGB). The abbreviations in the specimen number refer to the location of the fossil section (YN, the province of Yunnan; JS, GS, and GLF correspond to the quarry of Jianshan, Guanshan reservoir and Gaoloufang respectively).

3. Systematic Palaeontology

Phylum Arthropoda [11]
Phylum Euarthropoda [12]
Subphylum Mandibulata [13]
Order Hymenocarina [14]
Waptiidae [1]
Waptia [1]
Waptia sp. indet
Figure 1.A-C

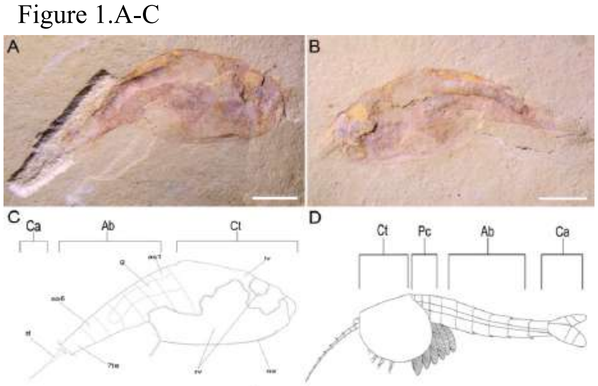

Figure 1. The specimen of YN-GLF-831 and the reconstruction of *Waptia fieldensis*

Note:

(A) counterpart of the specimen of YN-GLF-831; (B) part of the specimen of YN-GLF-831; (C) line drawing of (A); (D) reconstruction of Waptia fieldensis, revised from Vannier et al., 2018; Abbreviations are as follows: Ab, abdomen; as, abdominal segment; Ca, cauda; Ct, cephalothorax; g, gut; lv, left valve; mr, marginal rim; Pc, post-cephalothoracic segments; rv, right valve; ?te, the possible telson; tf, tail fluke; Scale bar = 3 mm.

3.1 Material

One specimen (YN-GLF-831), from the Wulongqing Formation (Cambrian Series 2, Stage 4), Gaoloufang section (24.95916°N, 102.80539°E).

3.2 Description

Small specimen, ～ 18 mm (from anterior margin of carapace to distal tip of tail fluke), laterally compressed. General profile of carapace valves suboval; length/height ratio of valves ～ 1.15. Narrow line running along ventral margin of right valve represents marginal rim, as seen in *Clypecaris* [10].

Trunk of seven segments, emerging from posterior margin of the carapace. All segments taper evenly in width and increase in length posteriorly, the last being narrowest and longest, possibly representing the telson, as observed in *Waptia fieldensis* Walcott, 1912 [7] and *Clypecaris pteroidea* Hou, 1999 [15]. All segments are lacking appendages. Overall morphology of trunk corresponds to abdomen of *Waptia* (e.g. Caron and Vannier [8], Figure1. a-c; Strausfeld [7], Figure1. A). An isolated structure, preserved just behind possible telson, is spine-like and longer than any abdominal segment; its general profile and location suggest it is a tail fluke in lateral view.

First to fifth abdominal segment preserve a three-dimensional gut, 5 mm long and 1mm wide; boundaries of some abdominal segments are impressed on surface of gut fill.

3.3 Discussion

3.3.1 Preservation

The abdomen of this specimen curves downwards from the axis of the carapace, and a similar preservation mode was also observed in *Waptia fieldensis* (e.g. Vannier et al. [9], Figure1.c-d). But different from this, the curve seen in our specimen is possibly due to post-mortem decay, as evidenced by the slight disarticulation of the two valves and the separately preserved tail fluke. This specimen possibly experienced a period of decay before being buried by the fine sediment.

3.3.2 Identity

The species-level identity of the euarthropod described here cannot be confirmed, based only on one incomplete specimen and the fact that no soft parts (e.g. eyes, limbs,

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antennae) are preserved. But, judging from the general morphology, this animal probably has close relationship with *Waptia* (Figure 1.D). Therefore, we tentatively define it as a species of *Waptia*.

Another indeterminate species of *Waptia* from the Guanshan biota was reported by Hu et al. [16], which has a pair of stalked eyes and antennae, seven limbless abdominal segments and a tail composed of three flukes. Most of these features cannot be discerned in the species described here and, therefore, we cannot confirm whether the two are the same.

3.3.3 *Waptia*-like euarthropods

To date, six small bivalved euarthropods have been discovered in the Burgess Shale-type biotas in the Early Cambrian of eastern Yunnan, among which four are from Chengjiang Biota: *Chuandianella ovate* Lee, 1975 [17], *Clypecaris pteroidea* Hou, 1999 [15], *Synophalos xynos* Hou et al., 2009 [18], *Erjiecaris minuscule* Fu et al., 2014 [19]; one is from Xiaoshiba Biota: *Clypecaris serrata* Yang et al., 2016 [10]; two indeterminate ones are from Guanshan Biota: *Waptia* sp. Hu et al., 2013 [16] and *Waptia sp*. here. In view of the lack of soft tissues, especially those beneath the carapace, the phylogenetic positions of these euarthropods remain unclear. In addition, *Clypecaris serrate* has a raptorial appendage and the visual organs of *Erjiecaris minuscule* are situated on the carapace, all of which differ from the characteristics of a classic waptiid. But all waptiids have a fixed body design: a large carapace composed of two valves covering the anterior part of the trunk, a limbless abdomen stretching out of the posterior margin of the carapace and a telson with two flukes being situated distally (Figure 1.D). All the bivalved euarthropods mentioned above firmly accord with these fundamental characteristics, and therefore it is reasonable to define them as *Waptia*-like euarthropods.

Class and order uncertain

Family Clypecarididae [15]

Genus *Clypecaris* [15]

Clypecaris pteroidea Hou, 1999 [15]

Figure 2.A-D

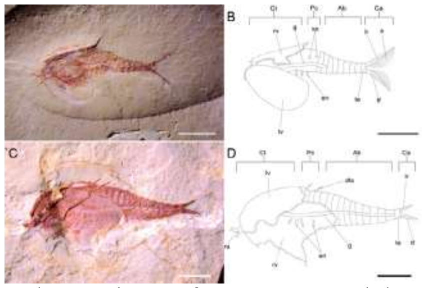

Figure 2. The specimen of YN-JS-500 and the specimen of YN-GS-001.

Note:

(A) the specimen of YN-JS-500, Clypecaris pteroidea from Chengjiang biota; (B) line drawing of (A); (C) the specimen of YN-GS-001, Clypecaris serrate from Xiaoshiba biota; (D) line drawing of (C); Abbreviations are as follows: Ab, abdomen; Ca, cauda; Ct, cephalothorax; dts, dorsal trunk spine; en, endopod; g, gut; lr, longitudinal ridge; lv, left valve; Pc, post-cephalothoracic segments; ra, raptorial appendage; rv, right valve; s, setae; ss, spine sockets; te, telson; tf, tail fluke; Scale bar = 3 mm.

3.4 Material

One specimen (YN-JS-500), from the Maotianshan Shale Member of the Yu'anshan Formation (Cambrian Series 2, Stage 3), Jianshan section (24.77036°N, 102.57877°E).

3.5 Remarks

The specimen is an almost complete individual preserved in oblique left-side view, different from that of the holotype [15]. The left valve is preserved in almost complete profile, whereas the right valve is barely preserved, with most parts missing. The valves are broken along the hinge articulation, exposing the tissues beneath. Due to the poor preservation, only the convex gut and three endopods, each of which is composed of two or three podomeres, can be discerned. Two subcircular structures, with an average diameter of 0.2 mm, are situated on the segment just behind the right valve. Based on the morphology and relevant position, these two structures should represent the spine sockets observed in *Clypecaris serrate*. The paired stalked eyes, antennae and the appendages of the segments, protruding beyond the posterior margin of the carapace on the holotype [15], cannot be discerned in the specimen herein, possibly due to the post-mortem decay. The length of the specimen, ~ 10 mm, is slightly shorter than the holotype (12 mm, excluding eyes and antennae), which possibly indicates it a juvenile of this species.

Clypecaris serrata Yang et al., 2016 [10]

3.6 Material

One specimen (YN-GS-001), from the Hongjingshao Formation (Cambrian Series 2, Stage 3), Guanshan reservoir (24.82766°N, 102.84242°E).

3.7 Remarks

The specimen, with 15 observable trunk tergites, is compressed laterally, the total length (excluding the raptorial appendage) of which is ~ 14 mm. Both valves are poorly preserved, with most parts missing. Compared to the specimens in literature [10], this one preserves some limb impressions on the inner surface of the right valve.

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The limbs (at least 4 pairs) are situated under the impression of gut, each of which has one or two observable podomeres. This is the first specimen showing the structures covered by the carapace but, due to the poor preservation, other organs and the related tissues beneath the carapace cannot be clearly discerned.

4. The Temporal and Spatial Distribution of *Waptia*-like Euarthropods in Early Cambrian, Eastern Yunnan

Chengjiang, Xiaoshiba and Guanshan are the leading examples of Burgess-Shale type biotas in the Early Cambrian of eastern Yunnan, and the time span between the first and the last could be as much as 7 million years (Figure3). Well preserved *Waptia*-like euarthropods first appeared in the Chengjiang biota and then were discovered in the other two, without any apparent time break, which indicates that this taxon is not confined to any specific biota, but has had existed for a rather long time. The relevant sedimentological analyses show that these three biotas are deposited in different palaeoenvironments with different water depths (e.g. Hu et al. [16]; Hou et al. [20]) and this may suggest that this kind of small bivalved euarthropod has a relatively strong viability and can survive different water environments, which can be further confirmed by the presences of this taxon in the Middle Cambrian biotas (e.g. Burgess Shale Fauna in Canada and Kaili Biota in China).

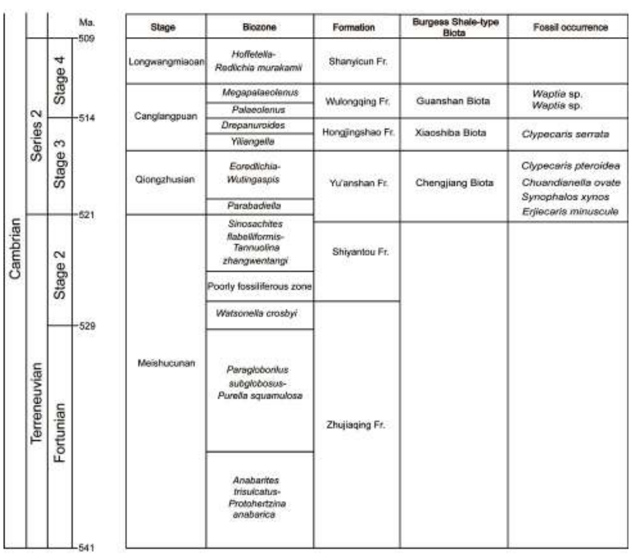

Figure 3. Stratigraphy of the early Cambrian, eastern Yunnan and the associated occurrences of *Waptia*-like euarthropods, revised from Hu et al. [16].

Clypecaris pteroidea was first discovered in the Xiaolantian section [15] and the specimen described herein was excavated in the Haikou area. Specimens of *Chuandianella ovate* from the Chengjiang biota were discovered at the Maotianshan section and in the Haikou area. Hitherto, *Synophalos xynos* was only known in the Haikou area and *Erjiecaris minuscule* is confined to the Jinning area. The holotype of *Clypecaris serrate* was discovered in the Xiaoshiba area, while the specimen described herein was excavated near the Guanshan resevoir. Both of the two indeterminate species of *Waptia* were discovered at the Gaoloufang section. The geographic map shows that all these fossil sections are situated around Dianchi Lake and cover a rather wide region (Figure 4). This area lay at the southwestern side of the Yangtze Platform in the Early Cambrian which is considered to represent a terrigenous clastic sedimentary basin, in which mud constitutes a considerable part of the sediments [16]. Benefiting from such unique sedimentary conditions, specimens of these small *Waptia*-like euarthropods can be exceptionally preserved.

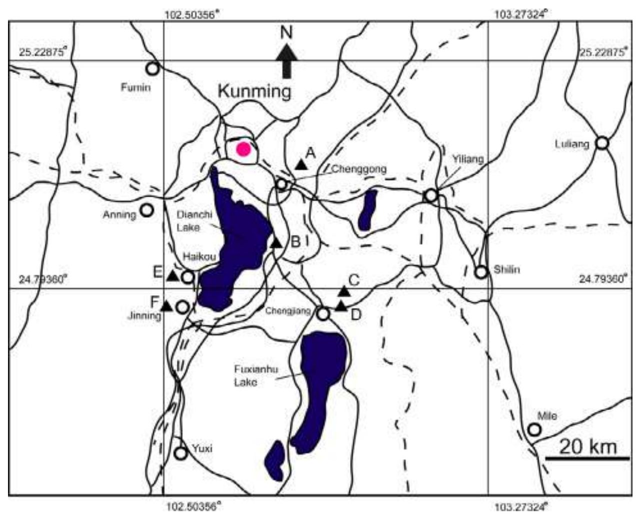

Figure 4. Fossils sections of *Waptia*-like euarthropods around the Dianchi Lake

Note:

A, Gaoloufang section; B, Guanshan reservoir; C, Xiaolantian section; D, Maotianshan section; E, Haikou area; F, Jinning area

5. Conclusion

Although lacking soft parts, a bivalved animal described from the Guanshan biota is considered to be a euarthropod in the genus *Waptia*.

The mode of preservation and length of the two specimens of *Clypecaris pteroidea* are variable. There are limbs underneath the carapace of *Clypecaris serrate*, which can number up to 4 pairs at least.

Waptia-like euarthropods lived for a rather long time (at least 7 million years) in the Early Cambrian of eastern Yunnan, and the relevant fossil sections cover a wide area

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around Dianchi Lake.

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ARTICLE

Sensitivity Analysis Of Geographical River Boundary Layers

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ABSTRACT

Bank full discharge is generally considered to be the dominant steady flow which would generate the same regime channel shape and dimensions as the natural sequences of flows would. This is because investigation on the magnitude and frequency of sediment transport have determined that for stable rivers the flow which in the longer term transports most material has the same frequency of occurrence as bankfull flow. For stable gravel-bed rivers, this is considered to be the 1.5-year flood.

1. Introduction

The objective of regime theory is to predict the size, shape, and slope of a stable alluvial channel under given conditions. A channel is characterized by its width, depth, and slope. The regime theory relates these characteristics to the water and sediment discharge transported bye the channel empirically. Empirical measurements are taken on channels and attempts are made to fit empirical equations to the observed data. The channel characteristics are related primarily to the discharge but allowance is also made for variations in other variables, such as sediment size.

For practical purposes, rivers are preserved to be in equilibrium (in regime) or in quasi-equilibrium of this characteristics have not changed over a long period of time. Canals usually maintain constant discharge and regime relations may, therefore, be established using field data. However, field measurements for rivers are not usually suitable for establishing laws for rivers in regime as pointed.

2. Analysis

2.1 Depth, Width and Slope

Natural rivers cover a wide range of discharge and slope, while the range of values for canals is relatively small. Lane (1957) observed that the stream width is a function of the slope and discharge. Therefore Lacey's relation

$$P = 2.67Q^{0.5} \quad (1)$$

cannot be applied to natural streams, because it contradicts the finding of Lane that steep. slope streams tend to be wider and shallower than streams of the discharge on a

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flat slope.

Depth

From analysis of the Kennedy (1994) data from the upper Bari Doab canal system in which nonsilting velocities had been achieved by aggradation and widening, Lacey (1930) plotted nonsilting velocity V_0 and hydraulic radius R,

$$V_0=1.17R^{1/2} \quad (2)$$

which was comparable to Kennedy's

$$V_0=0.84y^{0.64} \quad (3)$$

where y is the average depth excepting sides.

Width

Lacey plotted wetted perimeter P versus discharge Q, and fitted the equation

$$P=2.67Q^{1/2} \quad (4)$$

The Madras canals were wider and the Bari Doab canals were narrower.

Slope

Lacey employed his own form of the Manning equation:

$$V=\frac{1.3458}{n_a}R^{3/4}S^{1/2} \quad (5)$$

where n_a is the absolute channel roughness. The relations among silt factor, silt size, and channel roughness, he used velocity, hydraulic radius, bed material, and n. The silt factor was calculated from equation (2.8), and R. Kutter's n and Manning's n were known. The value of n_a was defined as Singh [70]

$$n_a=0.0225f^{1/4} \quad (6)$$

2.2 Regime Theory and Geometric Models of Alluvial Channels

An equilibrium state of river behavior is given as the regime concept (Kennedy, 1989, Ackers, 1992a). The study of the dimensions of stable alluvial canals, namely surface widths, cross-mean depths and stream wise slopes are called as regime canals. For predicting the dimensions of a regime fluvial channel from regime theory, a geometric model was also developed in order to design the full cross-sectional shapes of stable alluvial channels.

An alluvial channel can adjust its slope, depth and width, to develop a dynamic stable condition in which it can transport a certain amount of water and sediment (Ackers, 1992a). Empirical regime theory and analytical regime theory are two existing approaches. The field data is used to determine the empirical relationships from data. The two sets of equations are given for analytical regime theory, one for sediment transport and the other for frictional resistance. These equations were derived by relating the width to the discharge based on extensive data collected from the field. The development of rational regime relationships are interrelated by various analytical approaches. One type of approach introduces extremal hypotheses, such as minimum stream power [15,16] or maximum sediment concentration [74,75]. Others types of approach introduce a physical condition, such as bank stability (Ackers, 1980, Stevens [72] and Thorne, 1982), critical bank shear (Singh [69]), or lateral turbulence diffusion (Parker, 1978 a, b).

2.3 Numerical Modeling of Fluvial Processes

The study of the hydraulic geometry properties is very appropriate for natural stable channels. During the last decades it has seen that the transient behavior in fluvial processes are also of interest in river engineering. As a result numerical fluvial models have developed quickly in recent years. These models are used for calculating channel-bed degradation and aggradation (or scour and fill), and changes in bed topography. The theory of a numerical model for any fluvial process is given by response of the river's constant adjustment towards dynamic equilibrium. It has been observed that the dynamic equilibrium may never be actually reached in nature because of the changes in supply. Consequently, as an equilibrium condition the results of a long-term simulation of changes in the river behavior should approach the regime channel.

However, the present river numerical models suffer from the dependency on many empirical coefficients and assumptions concerning the treatment of sediment transport and turbulent structure of the flow field. Therefore these models are more or less limited to specific situations.

2.4. Modeling Width Adjustment of Alluvial Channels

The first numerical model for erodible channels dealing with width adjustment was developed by Chang [12].

Some of these models determine the migrative rates of both river banks using the concept of basal endpoint control (Darby & Thorne, 1994). Darby and Thorne (1994) stated that no model is currently able to simulate the flow within the crucial zone adjacent to the outer bank.

2.5. Aims and Objective of the Hydraulic Geometry Research

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The aim is to find a way of combining laws of deterministic fluid mechanics and probability theory in river engineering. The general objectives are therefore to:

(1) find a new way for river engineering research by combining the deterministic laws of fluid mechanics with the probability theory.

(2) gain an improved understanding of the mechanisms involved in regime theory and consequently to find certain similarities between numerous existing regime equations.

(3) Provide a computer-based hydraulic geometric model of stable alluvial channels for use in engineering applications.

2.6. Theoretical Background

Improving regime theories and geometric models of stable alluvial channels as well as fluvial numerical models are very important for river regulation because of their use in solving river engineering problems (Ackers, 1992a; Cao, 1987; Cao et al, 1987 and Yalin [106]). The deficiencies in models were pointed out by the National Research Council of USA (1983) as: (1) unreliable sediment discharge function; (2) inadequate formulation of the friction factor of erodible channels; (3) inadequate understanding and formulation of bed armouring and its effect on sediment discharge and friction factor; and (4) inadequate understanding and formulation of bank erosion mechanics. The accuracy of regime theories, geometric models and fluvial models depends ultimately upon the physical foundation, numerical techniques, and physical relationships for momentum, flow resistance, sediment transport, and bank erosion.

2.7. Boundary Shear Stress Distribution

Bank protection, sediment transport and width adjustment can be explored by the boundary shear stress distribution. There are either numerical methods (Keller & Rodi, [42]; Wormleaton [76]) or analytical methods [58] based on two-dimensional approaches. Three-dimensional turbulence models have also been developed and applied in order to study the pattern of secondary flow cells and the structure of the shear layer region (Kawahara & Tamai [41]; Krishnappan & Lau [59]).

2.8. Basic Approaches Ignoring the Effect of Secondary Currents

The basic approaches to calculate boundary shear stress distributions can be listed as following:

(1) Hydraulic radius method

$$\tau=\gamma RS \quad (7)$$

where τ=boundary shear stress, γ = unit weight of water, R= hydraulic radius; S= slope of water surface. It does however express the overall mean value for all shapes of cross section.

(2) Vertical depth method

$$\tau=\gamma hS \quad (6)$$

where h= vertical water depth. A fair approximation is obtained if the local boundary shear at any point is assumed to correspond to its vertical depth of flow immediately above the boundary.

(3) Normal depth method

$$\tau=\gamma h_n S \quad (9)$$

where h_n=depth along the normal depth of flow. If the inclination of the bed along the transverse direction is appreciable, then it will be found somewhat better to calculate the boundary shear by means of the depth at right angles to the bottom.

(4) Area method

The area method, which is an extension of the normal depth method, gives

$$\tau=\gamma h_n S(1- j/2) \quad (10)$$

here j= ch_n ; c= curvature of bottom. It is more consistent to let the boundary shear correspond to the area between two normals.

However none of the previous four methods properly considers the transfer of shear in the transverse direction of flow.

(5) Extended area method

Lundgren and Jonsson (1964) extended the Prandtl's turbulence theory to take into account the transfer of momentum across normals to the bottom of the channel. They developed a modified area method to determine the bottom shear stress in shallow, symmetrical channels with a rough bottom and gently varying bottom curvature as

$$\tau=\gamma \bar{h} S \quad (11)$$

where $\bar{h}=h_n a$= effective depth; a= a factor which is a function of the transverse bed slope. However this method can not be used on polygonal shapes, such as a trapezoidal section.

(6) Modified area method

Based upon the original area method by Lundgren and Jonsson (1964), Parker (1978b) and Ikeda et al (1988) developed a modified area method as

$$\tau = \rho g S \frac{dA}{dP} + \frac{d}{dP}\int_0^{h_n} \tau_{nx} dn \quad (12)$$

where ρ=the density of fluid; dA= the area between normals to the bed; dP= the wetted perimeter above dA; n= a spatial co-ordinate along normals to the bed; τ_{nx}= the local downstream-directed shear stress induced by turbulence which acts on the normals.

2.9. Boundary shear stress theory by Knight et al (1994)

Some understanding of the lateral distribution of depth-mean velocity and boundary shear stress in channels of complex shape is given by Knight [47,48,49,50,51, 52,53] Knight et al, [43,45, 46, 38, 48,49, 1985, 57, 52, 67, 55, 50, 87] Shiono and Knight, [53, 55, 68] . High quality experimental data from their laboratory and the SERC-FCF provide a foundation for their theoretical analysis.

Shiono and Knight [68] combined the equation for longitudinal stream

$$\rho\left[\frac{\partial U}{\partial y}+\frac{\partial UW}{\partial z}\right]=\rho g S_o+\frac{\partial}{\partial y}\left(-\rho\overline{uv}\right)+\frac{\partial}{\partial z}\left(-\rho\overline{uw}\right) \qquad (13)$$

where x, y, z are streamwise, lateral and normal directions respectively, U, V, W are temporal mean velocity components corresponding to x, y, z, and u, v, w are turbulent perturbations of velocity with respect to the mean, r is the density of water, g is the gravitational acceleration, S_o is the bed slope gradient (S_o=sin q). Integration gives

$$\frac{\partial H(\rho UV)}{\partial y}=\rho g H S_o+\frac{\partial H\bar{\tau}_{yx}}{\partial y}-\tau_b\left(1+\frac{1}{s^2}\right)^{1/2} \qquad (14)$$

where t_b is the bed shear stress, s is the side slope (1:s, vertical:horizontal). Based on the eddy viscosity approach, the analytical solution to Eq. 8 is derived for a constant-depth domain as

$$U_d=\left[A_1e^{\gamma y}+A_2e^{-\gamma y}+\frac{8gS_oH}{f}(1-\beta)\right]^{1/2} \qquad (15)$$

for a linear-side-slope boundary conditions given as

$$U_d=(A_3\xi^{\alpha_1}+A_4\xi^{-\alpha_1-1}+\omega\xi+\eta)^{1/2} \qquad (16)$$

where

$$\gamma=\left(\frac{2}{\lambda}\right)^{1/2}\left(\frac{f}{8}\right)^{1/2}\frac{1}{H},\ \beta=\frac{\Gamma}{\rho g S_o H}$$

$$\alpha_1=-\frac{1}{2}+\frac{1}{2}\left(1+\frac{s(1+s^2)^{1/2}}{\lambda}(8f)^{1/2}\right)^{1/2}$$

$$\omega=\frac{gS_o}{\frac{(1+s^2)^{1/2}}{s}\frac{f}{8}-\frac{\lambda}{s^2}\left(\frac{f}{8}\right)^{1/2}}$$

$$\eta=-\frac{\Gamma}{\frac{(1+s^2)^{1/2}}{s}\rho\left(\frac{f}{8}\right)}$$

$$\Gamma=\frac{\partial(H\rho UV)_d}{\partial y}$$

and ξ=H-((y-b)/s), which is the depth function on the side-slope domain for the main-channel side slope.

2.10. Flow resistance

The resistance of flow in a loose boundary channel is composed mainly of bed resistance and and wall resistance. Bed resistance can be further divided into surface drag and bed form drag. The devised bed resistance approach can be commonly expressed by two approaches. One is in terms of the energy slope, developed in Europe by Meyer-Peter and Muller (1948), as

$$S= S'+S'' \qquad (17)$$

Another can be in termed of the hydraulic radius, given by Einstein (1942), as

$$R= R'+R'' \qquad (18)$$

where S' and R' are the energy slope and hydraulic radius resulting from surface grain roughness; S" and R" are the energy slope and hydraulic radius associated with form roughness. Multiplying Eq. 11 by gR gives the division for shear stress as

$$\tau=\tau'+ \tau'' \qquad (19)$$

Dividing Eq. 13 by $\rho U^2/8$ gives the division for friction factor as:

$$f=f'+f'' \qquad (20)$$

where τ' and f' are counterparts to S' and τ" and f" are counterparts to S".

2.11 Grain Resistance and Flow Resistance Parameters

The Chezy resistance factor, C, is not dimensionless, it is common to let C=C'√g, and write

$$U= C\sqrt{gRS}= CU_* \qquad (21)$$

The Darcy-Weisbach formula for open channel flow can be presented as

$$U/U_*=\sqrt{8/f} \qquad (22)$$

or

$$\tau_b= (f/8)\ \rho\ U^2 \qquad (23)$$

The three friction factors are related to each other by

$$C/\sqrt{g} =(1/n)R^{1/6}/\sqrt{g}=\sqrt{8/f}=U/U_* \qquad (24)$$

In channels with sand or gravel boundary, the flow resistance in the absence of bed forms can be considered to be mainly caused by grain roughness. The well-known grain roughness formula based on Manning's is given by Strickler (1923) as

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$$n=d_{50}^{1/6}/21.1 \quad (25)$$

Substituting Eq. 19 into Manning's formula gives the Manning-Strickler formula

$$U/U_*=6.74(R/d_{50})^{1/6} \quad (26)$$

Meyer-Peter and Muller (1948) developed a similar formula for sand mixtures as

$$N= (d_{90})^{1/6}/ 26 \quad (27)$$

where d_{90} is the size (in metres) for which 90% of bed material is finer.

Einstein presented a logarithmic resistance equation for plane sand bed:

$$U/U_*= 5.75 \log (12.27 d/\Delta) \quad (28)$$

where $U_*=\sqrt{gRS}$ is the shear velocity resulting from grain roughness, D is the apparent roughness which is related to equivalent roughness k_s by

$$\Delta= k_s/ X = d_{65}/X \quad (29)$$

The parameter X is a correction factor which accounts for the variation in flow regime. The value of X is given as a function of the laminar sublayer thickness δ. In the region of rough wall, X is unity and thus Δ and k_s are identical.

2.12 Form Resistance

The evaluation of the form resistance is more complicated. Different resistance laws are required for different bed forms. The transition between particular bed forms may require special relationships.

(1) Einstein and Barbarossa's method (1952)

A function was therefore suggested for the lower regime flow:

$$U/U_*''=F(Y') \quad (30)$$

where Ψ is the intensity of shear on representative particles and is given by

$$\Psi'_{35} = \frac{\rho_s-\rho}{\rho}\frac{d_{35}}{R'S} \quad (31)$$

The functional relationship for Eq. 24 was based on field data in the form of a diagram for ease of application.

(2) Engelund's method (1966)

Engelund's method employs the divided slope approach and assumes that S=S'+S", where S' is due to skin friction and S" is due primarily to expansion losses associated with flow separation downstream of dune crests as

$$S''= \Delta H''/\lambda=(\alpha k^2/2\lambda h)F^2 \quad (32)$$

where ΔH" is the expansion head loss due to bed forms with a wave length of λ, α is the loss coefficient, k is dune height, h is mean depth of water. Substituting Eq. 26 into Eq.11

yields

$$S=S'+(\alpha k^2/2\lambda h)F^2 \quad (33)$$

Multiplying both sides by $\gamma R/(\gamma_s-\gamma)d$ gives

$$\frac{\gamma RS}{(\gamma_s-\gamma)d}=\frac{\gamma RS'}{(\gamma_s-\gamma)d}+\frac{\alpha}{2}\frac{\gamma h^2}{(\gamma_s-\gamma)\lambda d}F^2 \quad (34)$$

Assuming

$$\Theta=\frac{\gamma RS}{(\gamma_s-\gamma)d}$$
$$\Theta'=\frac{\gamma RS'}{(\gamma_s-\gamma)d}$$
$$\Theta''=\frac{\alpha}{2}\frac{\gamma h^2}{(\gamma_s-\gamma)\lambda d}F^2 \quad (35)$$

then Eq. (28) becomes

$$\Theta=\Theta'+\Theta'' \quad (36)$$

where,

θΘ,Θθ' and Θθ" are the dimensionless total shear, shear due to grain roughness, and shear due to bed-boundary layer roughness, respectively. Using flume data, Engelund and Hansen (1967) obtained the following relationship for lower regime with a ripple or dune bed (for Θθ'<0.55):

$$\Theta'= 0.06+0.4\,\Theta \quad (37)$$

For the upper regime flow with 0.55 < Q'< 1, the relationship becomes

$$\Theta'= \Theta \quad (38)$$

2.13 Discussion

As a basis for concluding the discussion, a sensitivity analysis on the hydraulic geometry of stable channels will now be conducted using the five key parameters and the new geometric model. Based on the results of this sensitivity analysis, the general behaviour of depths, surface widths and streamwise slopes of stable alluvial channels are discussed. Furthermore the new concepts proposed in this chapter are connected together and coupled with other necessary existing relationships to construct a new rational regime theory.

2.14 Sensitivity Analysis of Five Parameters

The parameters to be tested are:

1. median grain diameter of the boundary, d_{50};
2. gradation of the boundary material, $\xi=d_{90}/d_{50}$;
3. the bank stability index, σ;
4. longitudinal slope, S, and
5. discharge, Q.

The resulting curves of calculated values, expressed as number 1 to 7, are shown in Table 1 and 2, respectively. The curves are

1.channel average-depth, H_a, in cm;
2.channel centre depth, H_c, in cm;
3.cross-sectional mean velocity, U, in cms^{-1};
4.surface width, B, in m;
5.bed width, b, in m;
6.bank width (B-b), in m; and
7.aspect ratio, B/H_c.

Table.1 Observed data of the channel, (Andrews [8])

Bankfull Discharge (m^3s^{-1}) 255	Bankfull depth (m) 1.85	Bankfull width (m) 83.8	Bankfull velocity (ms^{-1}) 1.64
Slope X10^{-3} 0.88	d_{50} of river bed (m) 0.034	d_{90} of river bed (m) 0.082	Bank vegetation type : Thick or thin Thin

Table. 2 Sensitivity

Parameters to be tested	(1) d_{50} (mm)	(2) d_{90}/d_{50}	(3) σ	(4) Sx1000	(5) $Q(m^3s^{-1})$
Values tested	20-40	2-4	1-2	1-2	500-1000
%increased	100	100	100	100	100
H_a (cm) Change by %	145-256 76	249-291 17	228-400 75	206-110 −47	240-247 3
H_c (cm) Change by %	150-300 100	287-367 28	255-510 100	224-112 −50	255-255 Constant
U(cms^{-1}) Change by %	163-222 36	212-222 5	207-244 18	205-186 −9	210-212 1
B(m) Change by %	107.8-45.0 −58	48- 39 −8	54-26 −52	61-124 103	99-190 92
b(m) Change by %	97.8-25.0 74	29-15 49	37-9 75	46-117 154	82-173 112
B-b (m) Change by %	10-20 100	19-24 28	17-17 Constant	15-7.5 50	17-17 Constant
B/H_c Change by %	72-15 79	17-11 36	21-5 76	29-113 290	41-77 87

Analysis results of five parameters on:1. Channel average-depth, H_a, in cm; 2. Channel centre depth, H_c, in cm; 3. Cross-sectional mean velocity, U, in cms^{-1}; 4. Surface width, B, in m; 5. Bed width, b, in m; 6. Bank width B-b, in m; and 7. Aspect ratio B/H_c [8].

2.15. Influence of Median Grain Diameter of Boundary Material, d_{50}

Constant input variables: discharge, $Q=255\ m^3s^{-1}$, longitudinal slope, S=0.00088, gradation of boundary material, $\xi=d_{90}/d_{50}=1$, bank stability index, σ=1, β=0.15, μ=0.6, $\rho^*=(\rho_s - \rho)/\rho = 1.65$) are given in sensibility analysis. It is very obvious that d_{50} exerts a strong influence on the hydraulic geometry of a stable alluvial channel. For example, increasing d_{50} by 100% from 20 mm to 40 mm causes the cross-sectional average depth, H_a, to increase by 76% (from 1.454 m to 2.556 m); the centre depth, H_c, to increase by 100% (from 1.5 m to 3.0 m); the cross-sectional mean velocity, U, to increase by 36% (from 1,626 ms^{-1} to 2.216 ms^{-1}); the surface width, B, to decrease by 58% (from 107.8 m to 45.0 m); the width of bank region, B-b, to increase by 100% (from 10 m to 20 m); the aspect ratio, B/H_c, to decrease by 79% (from 71.9 to 15.0); and the width of centre bed region, b, to decrease by 74% (from 97.834 m to 25.046 m). The results show that for given constant input condition the stable Type-A channel will approach a Type-B threshold channel for a median grain diameter of boundary material somewhat larger than 60 mm. In this case, the size of bank material is big enough to keep a large stable centre depth with a enough cross-sectional area to transport the given discharge. As a result, the sediment transport is vanished and the centre bed zone cannot be formed (Ackers and Charlton, 1970a, b, Ackers, 1972, 1992a).

3. Results

The surface width equation is employed as

$B= 4632 (H_a^2S/d_{50})^{1.5}$

The complete set of rational regime equations are given as:

$S = a_1\ d_{50}^{1.079}/Q^{0.359}$

$H_a= a_2Q^{0.359}/\ d_{50}^{0.079}$

$B = a_3Q^{0.539}/\ d_{50}^{0.119}$

$U = a_4\ Q^{0.102}d_{50}^{0.198}$

$Q_s= a_5\ Q^{0.736}d_{50}^{0.778}$

where Q_s= cross-sectional sediment discharge at bankfull discharge in kgs^{-1}. The coefficients, a_1 to a_5, were the functions of the coefficient, a, and calibrated from observed values of Q, d_{50}, S, H_a, B, Q_s, and U by 53 set data published by Bray (1979), Lane et al (1953) and Ikeda

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(1988) as a_1= 0.360, a_2=0.168, a_3= 2.852. a_4= 1.923 and a_5= 2.170. The comparison of the observed data and the calibrated equations are given. The scatter of the observed data around the line given by the equations is acceptable for B, H_a and U. In the case of slope equation the observed data show considerable scatter, perhaps mainly due to the fact that slope is a difficult parameter to measure accurately (Parker, 1979).

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